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THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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CONTRIBUTIONS OF BOTANY TO TROPICAL AGRICULTURE.

AMONG the sciences that contribute to agricultural and horticultural progress, none has closer or more multifarious contacts with practical crop production than botany. If such contacts are apparent only to those most intimately concerned with agricultural research, the reason is to be sought in the comparative neglect of botany in the general educational system, which leaves the average layman under the impression that its main function is to give plants long names.

The science of knowing plants has inevitably been connected from the earliest times with the art of growing them. Its development can in fact be traced from the "physic gardens" of the Middle Ages, which served both medicine and horticulture, to the botanic gardens of later times with a distinguished record of services in the collection, identification and dissemination of useful plants all over the world (1). The latter perhaps reached the zenith of their importance in the Tropics during the nineteenth century, with the establishment of tea in India, cinchona in Java, and rubber in Ceylon and Malaya. Some remain, and to-day discharge wider functions than ever. Others have disappeared or lost their identity in agricultural departments. But the closing years of the nineteenth century and the early years of the twentieth saw the rise of tributary activities which have continuously broadened the course of botanical investigation ever since.

It was during this period that a growing realization of the enormous losses occasioned by insect pests and plant diseases called new specialists to the assistance of agriculture, on the one hand entomologists and on the other botanists who had devoted particular study to the group of plants called fungi. The entomologists and mycologists speedily justified their election and made great advances in the study of their problems. The demand for their services increased, and special courses of training were instituted in certain cases to meet the need. Reciprocally as the number of workers grew, investigations were pushed deeper, and it became

(1) This has been admirably done by Sir David Prain in a Sir George Birdwood Memorial Lecture delivered before the Royal Society of Arts in 1925, under the title of "Government Botanic Gardens." (*J. Roy. Soc. Arts*, 73 (1924-25) 271.)

increasingly evident that the study of the host plant was not the least important part of the campaign. These successes had both a general and a particular effect on the position of botany in agriculture. They stimulated a general interest in the potentialities of applied research, and they revealed a need for the co-operation of botanists who had specialised along rather different lines.

Particularly, perhaps, was the latter the case when the most promising possibilities of disease or pest control were found to lie in the substitution of resistant varieties of crop plants for susceptible varieties formerly grown, and extensive operations in plant breeding became involved. By a fortunate coincidence the rediscovery of Mendel's laws of heredity occurred during the same period of development, the basis of plant breeding was at last made sound and clear, and fresh emphasis was thrown on the constitution of the individual plant as a factor in agricultural success.

The position which botany has reached in the post-war development of agricultural research services is superficially obscured by a multiplicity of specialist labels. Problems are becoming more and more complex as knowledge advances, and demanding progressively more technical skill in diverse directions, which can only be obtained by increasing specialisation. Hence we find on the staffs of agricultural departments and research institutions officers described as plant physiologists, geneticists, plant breeders or cytologists, as well as economic botanists, systematic botanists, ecological botanists, and occasionally just simply botanists. A few of these labels may be useful to distinguish the main branches of a very big subject, but they tend to conceal three important facts, the first that all these specialists have a similar fundamental training, the second that it is rarely either possible or desirable for a botanist to restrict himself to one aspect of his science, and the third that in the end it must always be within a framework of general botanical principles that the contributions of specialists are fitted together for translation into improved agricultural practice.

A similar tendency is responsible for the use of labels such as "economic" to distinguish botanists who are working on agricultural, horticultural or technological problems from those who are not. This leads in turn to a distinction being sometimes drawn between "pure" and "applied" or "economic" botany, whereas in point of fact there is no such division in the science. Considerable difference in outlook is inevitable between the botanist in agriculture, whose work is ultimately tested in terms of monetary profit or loss, and his academic brother whose achievement is assessed solely by his contributions to knowledge, "useful" or otherwise. Even this difference can easily be over-emphasised, since the one adds to knowledge whilst pursuing economic ends just as the other contributes to economic advances whilst pursuing knowledge for its own sake. Still, it undeniably does and must exist, and the unity of the science can be stressed more convincingly when divergences between its practitioners are frankly recognised. At the same time there appears only occasional need to distinguish by title the botanist in direct contact with crop production or plant industry from him whose contacts are indirect, and the more the two can realise their common interests the better it is for all concerned.

The outlook of the botanist in agriculture is determined by botanical analysis of crop production, and crop production represents the sum of interactions between constitution and environment. His problems therefore fall into two series, separable for purposes of discussion though interlocked in practice, those in crop genetics and those in crop physiology.

Provision to the agriculturist of genetically better planting material is perhaps the most important function of the botanist under present conditions. It is not only a matter of plant breeding, though breeding may play a conspicuous part in certain cases. The collection, introduction, comparison and classification of species and varieties of crop plants represent a direct legacy from the days when botanic gardens were the main centres of agricultural research, and are still as important as ever.

Collection and introduction are returning to favour after an interval under a cloud. It is highly regrettable that the carriage of crop plants from one country to another has so often involved the carriage of pests or diseases as well, with calamitous results to the importing countries concerned. Yet the benefits conferred on agriculture as a whole by plant exchanges were even in the past immeasurably greater than the pathological consequences at their worst, and the important point about this particular risk is that to recognize it is largely to nullify it. With modern methods of plant quarantine available as a safeguard, there is less reason than ever there was for refraining from plant introductions *under proper technical control.* Classification, and systematic studies generally, are the basis of botany and hence of crop improvement. The imperfection of our knowledge of the systematics of tropical crop plants at the present day is responsible for losses no less serious for being largely unsuspected. One variety of a crop may be known under a whole list of names in different countries, or conversely several distinct types may pass under one and the same name. Such a state of affairs hinders co-ordination of results between research centres, causes unnecessary introductions to be made in some cases and desirable introductions to be omitted in others, and creates a general confusion in which time and effort are wasted that have a real and considerable cash value.

Crop taxonomy has to be much more detailed than the branch of the subject that deals with wild species, since the characters that separate agricultural varieties are finer than those used

to differentiate species, and moreover are frequently as much physiological as morphological. Hence a herbarium technique is seldom applicable, and comparisons involve growing the varieties side by side and observing them at all stages. For similar reasons, type specimens, against which doubtful varieties can be compared for identification, should be maintained in the living condition as pure lines or clones if they are to be of real use, and the maintenance of type collections of tropical crops is a requirement as yet almost unfaced.

Studies of the origins and of the wild relatives of cultivated plants, in their bearings on the problems of collection, introduction and breeding, are scarcely less important than studies of the crops themselves. The centre of origin, if known, indicates the regions to be searched for types with new characters of agricultural value ; the manner of origin, if it can be deduced, guides the breeder to appropriate methods, and the use of *Saccharum spontaneum* in sugar-cane breeding is only one example among dozens of the direct value of wild plants to the raiser of new crop varieties.

Detailed studies of quantitative variability within a crop are usually indispensable preliminaries to actual breeding operations, and the botanist has to decide from them whether to proceed by hybridisation or by the less spectacular methods of simple selection that in mixed tropical crops are probably more frequently appropriate. The genetic survey of Trinidad cacao carried out between 1930 and 1934 provides many illustrations of the useful information that can be gleaned from such researches, particularly where perennial crops of long life-history are in question.

Selection of types among mixed crops is in itself a problem of no mean order. It involves at the outset a working definition of the word " best " for there is rarely if ever one " best " type for all conditions, and the aims of selection must be dictated by economic requirements. The relative importances of yield and quality have to be assessed in the light of some knowledge of local agricultural conditions and of the preferences of the markets, and before that can be done there must be an analysis of all the factors which go to build up yield, a similar analysis of factors contributing to quality in the crop, and a careful study of the interactions of the two sets of factors, which are sometimes antagonistic.

When hybridisation is found to be necessary, a new set of problems is opened up. Instances have been multiplied in recent years of advances achieved by intercrossing distinct botanical species, and everything points to a still greater use in the future of this particular method of crop improvement. Species crossing, whilst enlarging the potentialities of plant breeding, often presents its own difficulties to be overcome, and the microscopical examination of minute details of cell structure may have to be called to the aid of genetics for the direction of practical breeding. In banana breeding and sugar-cane breeding, for examples, as in the cases of several temperate fruits, cytology provides the only key to baffling behaviour in inheritance.

On the other hand, in cases especially frequent among perennial crops, such as cacao, the breeding of new types is of less immediate importance than correct propagation of the best among those already existing, and the task of elaborating propagation methods through research in plant physiology falls appropriately enough to the " plant breeder " in his wider capacity as a botanist.

Thus, if a team of specialists is available, there is work in genetic crop improvement for systematists, geneticists, cytologists and physiologists, but the common end is one, and frequently the various aspects are of necessity examined to the best of his ability by one individual. Neither the number of workers nor the funds available for research will at present allow a full team to every crop, and in any case each crop has its own peculiarities, and requires for its perfect investigation its own specially balanced team. Consequently the botanist, whatever his specialist label, must be able to appraise the situation from several angles and select the most appropriate lines of attack.

The function of botany in exploration of the relation of the plant to its environment is scarcely less important, though in this field it shares responsibility with soil science and with plant pathology. The joint problem is to discover and describe in detail how the crop plant lives and grows and builds up its yield, in surroundings partly pre-determined by geographical and topographical factors and partly modifiable by agricultural practice.

The physico-chemical complexity of the soil and the tremendous importance of soil conditions in plant growth render imperative for the investigation of soil problems other specialists whose fundamental training is in chemistry rather than in biology. Similarly the multiplicity of parasitic organisms, including both insects and fungi, as well as other groups, calls for specialists in entomology and mycology to cope with the problems of crop pests and diseases. For the rest, it is the botanist who is concerned with tracing the plant step by step through its life-history, observing the effect upon it of varying conditions at every stage, and especially at those stages which are found to be most critical in relation to final yield.

Critical stages in the life history of the plant occur particularly in the development of crops which are grown for their fruits or seeds, and are often connected with the processes of pollination and fertilisation. Plants of complex ancestry are liable to exhibit partial or complete sexual sterility, and barrenness in certain varieties when grown alone or in certain combinations has been traced to this cause for several kinds of crop plants both temperate and tropical. This is a

genetic aspect of a yield problem, but in other cases, unfruitfulness may be traced to other causes such as malnutrition, which are primarily physiological.

The environment also includes for the botanist the complex reactions of one green plant on another, and in the case of budded or grafted plants, which are coming more and more into cultivation as the necessity of uniformity in produce is realized, the reciprocal influences of stock and scion provide him with a wide field for research. In the case of some crops, such as fruits, which are marketed in a living state, he has even to concern himself with the environment of the produce in storage and transport, in co-operation with the biochemist and mycologist.

Finally it is to be remembered that the botanist in tropical agriculture often has functions outside even the wide range of crop plants and their wild relations. Studies of natural vegetation are being increasingly recognized as economically important. To the agriculturist opening up new areas, the wild plant population is a useful indicator of soil and climatic conditions. To the pathologist it is a reservoir whence come pests and diseases of crops, or, more happily, wherein can be found natural enemies of pests to be turned to good account in biological control. Vegetation studies are practically impossible without identification of plants, and in many tropical countries the local floras are very imperfectly known. Consequently the collection and identification of species quite unrelated to his crops may legitimately find a place among the activities of the "economic" botanist. In these and many other ways he makes essential contributions to that solid basis of general knowledge upon which alone the various agricultural sciences can build.

E. E. CHEESMAN.

AGRICULTURAL RESEARCH IN EAST AFRICA.

The Colonial Office has issued the sixth annual report (1933-34) of the East African Research Station at Amani (London: *H.M. Stationery Office.* 1s. *net*), from which it is evident that progress has again been made in all the various research activities with which the Station is concerned. As regards coffee investigations, the earlier impression that heavy applications of organic manures to *arabica* coffee effectively offsets the harmful influence of soil acidity has now been confirmed, while culture solution studies suggest a marked correlation between acidity of the medium and the degree of branching of the roots which occurs, high acidity being associated with an unbranched type of root system. Results of importance have also been obtained by the plant pathology section, as the vector of the mosaic disease of *Cassava* has been definitely proved to be a species of white fly (*Aleurodidae*). On the biochemical side comes the discovery that the fermentation of coffee is an unnecessary process so far as quality is concerned, though the difficulties of correlating quality with the method of preparation of the coffee are still not overcome. The cultivation of sisal (*Agave amaniensis*) continues to increase, and the first lot of seedlings raised at the research station are now becoming available for fibre tests, the standardisation of which has been considerably developed during the past year.—(*Nature*, Vol. CXXXV, No. 3424, 1935, p. 989.)

OBITUARIES.

MR. B. R. JONES.

IT is with deep regret that we have to record the death on 26th June, at Renala Estate, Punjab, India, of Mr. B. R. Jones who joined the College as a scholar of the Empire Cotton Growing Corporation in October 1931. Mr. Jones was educated at Llandovery College and the South-Eastern Agricultural College, Wye, where he graduated as B.SC. (London), and also obtained a Diploma in Agriculture. In 1933, after qualifying for the Associateship, he secured a post with the United Fruit Company in Jamaica which he held until he went to the Punjab where he was managing a large property. As a student his attractive and good natured personality won him many friends among both staff and students. He was a particularly good all round athlete but did not allow his fondness for sport to interfere with his work in which he was keenly interested. He recently became engaged to Miss Phyllis Littlepage, and we extend our sincerest sympathies to her and to his relations at their very sad loss.

* * *

MR. H. MUSK.

IT is with deep regret that we have learnt of the death of Mr. H. Musk who was a student at the College during the 1926-27 session. Mr. Musk was educated at the National School, Gringley on the Hill and the Ordination Test School, Knutsford. In 1925 he was awarded a Colonial Agricultural Scholarship, the first year of which he spent at the South-Eastern Agricultural College, Wye. Mr. Musk's varied experiences before he joined the Colonial Agricultural Service included that of journeyman gardener in Doncaster, specialist carnation grower at Sandringham and student gardener at the Royal Botanic Gardens. He was a seaman in the R.N.V.R. during the war. Mr. Musk obtained the Associateship of the College and was serving as District Agricultural Officer in the Tanganyika Department of Agriculture, until his untimely death.

GRAPEFRUIT INVESTIGATIONS IN TRINIDAD.

By F. Hardy and G. Rodriguez.
Imperial College of Tropical Agriculture.

[*Being a Summary of Results obtained since January, 1934, described in a Lecture to Members of the Citrus Growers' Association of Trinidad and Tobago, delivered on 24th April, 1935.*]

This article describes the main results obtained in a chemical investigation, commenced in January, 1934, of the soils of typical grapefruit fields in Trinidad, considered in relation to the requirements and effects of manurial treatments, as gauged by the composition of grapefruit leaves. It also presents some preliminary data on the composition and quality of grapefruits, in comparison with fruits grown in other countries.

The Specific Nutrient Requirements of Grapefruit.

In attempting to determine the suitability of the soils of Trinidad for the satisfactory growth of grapefruit of high quality, the first need is exact knowledge of the particular environmental conditions under which the plant thrives best.

The main differences between the growth environment of grapefruit in Trinidad and that in other countries, such as California, Florida, Palestine, Rhodesia, &c., are firstly, *climate*, (particularly rainfall, sunshine and temperature variation), and secondly *soil-type*.

Whereas grapefruit is grown under controlled irrigation in most countries, the planter in Trinidad depends solely on rainfall. For satisfactory growth, the grapefruit tree requires the equivalent of 75 inches of rain or over, per year (Clark Powell (1)). The tree also needs adequate sunlight, and therefore thrives best when widely planted (say at distances apart of 30 feet) without special shade trees. Low temperatures, such as occur during spells of frost in some countries, are harmful.

As regards soil, fairly deep (two feet at least) foam appears to be best, although the distribution ol the absorptive roots is largely decided by the water supply, and by the stratification of the soil. Thus, under irrigation in deep, uniform, sandy soils, the root system of the grapefruit tree is more deeply and widely penetrating, whereas under high rainfall conditions, and in soils that possess a marked organic upper layer, the feeding roots tend to occur mainly within a relatively shallow surface zone, which, in Trinidad, is probably seldom deeper than six inches, and often much less than this.

The most important *nutrient* elements needed by the grapefruit tree, in common with other crops, are nitrogen, phosphorus and potassium. Other necessary elements are calcium, magnesium, sulphur, chlorine, boron and iron, and certain important minor elements, such as aluminium, manganese, zinc and copper, may also be essential.

The exact amounts of the essential elements taken up by grapefruit doubtless vary within wide limits, depending on water-supply and other growth conditions, and on the age and the phase of development of the tree. The quantities available in the soil may be augmented by suitable manuring.

The Special Importance of Calcium in Grapefruit Nutrition.

Among the important elements, *calcium* appears to have special significance in the growth of the grapefruit tree, in common with most species of Citrus. The chief indications leading to this conclusion are :—

(1) The leaf-ash of normal, healthy grapefruit usually contains an exceptionally large amount of lime (calcium oxide), often as high as 50 per cent. of the weight of total ash. Even when grown in soils or in sand-cultures or water cultures, definitely deficient in available lime, the leaf-ash tends to contain a high proportion of lime. Grapefruit differs from many other tropical crops, such as cacao, in this peculiarity. Thus, where grapefruit and cacao are grown in the same or neighbouring

Table I.

Comparison of Composition of Leaf-Ash of Grapefruit and Cacao grown in similar soil of neighbouring fields (River Estate, Diego Martin, Trinidad).

	Soil (Surface 6 ins.)					Leaf-Ash.					
	Index of Texture.	Degree of Acidity.	Avail. Lime (CaO).	Avail. Potash (K_2O).	Degree of Satn. by lime.	Lime (CaO)	Potash (K_2O)	Magnesia (MgO)	Phosphate (P_2O_5)	Nitrogen (N).	Sum CaO + K_2O + MgO.
	I.T.	pH	Per cent.	Per cent.	Per cent.	Per cent. of Total Ash.					
Grapefruit	16	5.1	0.042	0.005	12.1	24.3	28.5	12.9	4.9	27.6	65.7
Cacao	25	5.6	0.142	0.006	33.3	12.1	32.2	11.2	8.9	33.0	55.5

fields, a striking difference in leaf-ash composition occurs. This fact is clearly indicated by the data contained in Table I, for trees grown at River Estate, Diego Martin, Trinidad.

Although the cacao soil is more than *three times* as rich in available lime as the grapefruit soil, and is much more highly saturated by lime, the leaf-ash of cacao contains only *half* the amount of lime as that of grapefruit.

(2) The higher the content of available lime (exchangeable calcium) in the grapefruit soils of Trinidad, the higher (in general) the content of lime in the grapefruit leaves. A significant degree of correlation between these two quantities has been established for 23 paired examples. (Coefficient of correlation = +0.675.) In the cases of most other crops, a cursory search of the literature has revealed no similar instance of such a close relationship between the amount of any particular nutrient in the soil and its amount in the leaf.

(3) An abundant lime supply in the soil appears to be necessary for healthiness and disease resistance of the grapefruit plant, as well as for other Citrus species. Thus Haas (a Californian authority) maintains that "a deficiency of soluble calcium may exert a tremendous effect upon the absorption process, and thereby upon the health of Citrus". (2)

In some of Haas' experiments with young orange trees grown in calcium-deficient sand and water cultures, premature leaf-shedding was frequently observed, together with subsequent formation of multiple buds exhibiting curled and chlorotic leaflets, or accompanied by severe die-back of twigs. These effects were associated also with excessive uptake of potassium. On the other hand, abundant calcium in sand or soil cultures diminished the uptake of potassium in harmful quantities, as well as that of harmful sodium, and the orange trees grew healthily.

(4) The ash of the fruit rind and juice of ripe grapefruits normally contain a high proportion of lime, just as in the case of the leaves. The large lime content of Citrus juices is often stressed as an important factor in the dietic value of the fruit (3). E. L. Lord states that mature Citrus fruits grown in different regions of Florida exhibit considerable differences in lime content (3). Thus, oranges grown in calcareous soil may contain 33 per cent. more lime (and proportionately less potash) than oranges grown in soil whose available lime content is small. One-tenth of the total production of Citrus fruits in Florida, according to Lord, "is derived from soils containing a high lime content", and the fruit "has consistently received an average of 30 to 50 cents a box more than the fruit from the rest of the State" (3).

(5) The yield and quality of Citrus fruits, including grapefruit, are frequently stated to have been markedly improved by liming the soil. Even spraying the leaves of the trees with lime water is claimed by Singleton (4) in Florida to cause oranges and grapefruits to mature nearly two months earlier, and to lessen leaf-infection by melanose and wax scale. Singleton also claims that spraying with lime water improves the flavour of the fruits, reduces rind thickness, and increases juice contents, but Miller, Basset, Thompson and English state that they obtained no change in chemical composition of the fruits of orange trees sprayed with lime water (5).

On the other hand, *excess* of lime in the soil, coupled with a highly alkaline soil condition, may be very harmful to Citrus, in that it may produce a form of chlorosis, or leaf mottling or frenching, with subsequent leaf shedding and dieback (2). A direct cause appears mainly to be suppression of available iron. Furthermore, an alkaline condition may also markedly diminish the actual uptake of lime. Even when the soil is neutral or acidic, but is rich in available lime, so that much lime is absorbed, the *potash* content of the leaf may be severely diminished, a strict reciprocal relationship obtaining between lime content and potash content of Citrus leaves. Low leaf potash content may reduce carbohydrate synthesis, and may also lessen resistance to leaf diseases, whereas high potash content may be associated with leaf mottling and premature leaf shedding (2).

(A) Soil Investigations.

The Grapefruit Soils of Trinidad.

In order to detect any particular deficiencies or excesses of nutrient elements in the grapefruit soils of Trinidad, soil samples were taken from representative fields for examination in the laboratory. They were procured at three depths, namely, 0 to 3 inches, 3 to 6 inches and 6 to 12 inches. Care was taken to sample only *unmanured* soil. Summarized laboratory data for different areas are presented in Table II, for the surface 3-inch layer of soil, in which most of the feeding roots seem to occur.

The following approximate arbitrary values for *deficiencies* in the four chief nutrient elements, based on experience in other countries as well as our own experience in Trinidad, have provisionally been accepted for grapefruit in Trinidad.

Deficiency in—

Total Nitrogen	0.075 per. cent.	or less.
Available Phosphate	50 p.p.m.	do.
Available Potash	200 p.p.m.	do.
Available Lime	2,250 p.p.m.	do.

It should clearly be understood that these limits for deficiencies are only tentative, and are intended merely to convey some idea of the general requirements of grapefruit growing under normal conditions as regard soil moisture, aeration and suitable drainage conditions in average loam soil.

Conclusions from Soil Analyses.

(1) The grapefruit soils of Trinidad belong to the sand category in the Northern Range areas, and to the clayey-silt category in the Central Range areas.

Table II.

SUMMARIZED LABORATORY DATA FOR TYPICAL GRAPEFRUIT SOILS OF TRINIDAD.

Area.	No. of Fields or Plots.	Index of Texture.	Degree of Acidity.	Org. Matter.	Total Nitrogen.	C/N Ratio.	Avail. Phosphate (P_2O_5).	Avail. Potash (K_2O).	Avail. Lime (CaO).	Lime Requirement Top 3 ins.	
		I.T.	pH.	%	%		Parts per million.			Tons per ac.	Lb. per tree.
(A) ST. AUGUSTINE EXPERIMENT STATION.											
Block A (West)	4	24	6.4	1.7	0.15	6.5	34	132	1,740	0.24	4
Block B (East)	4	28	6.9	2.0	0.17	6.8	40	96	2,400	0.00	0
(B) NORTHERN RANGE VALLEYS (West to East).											
Tucker	12	14	5.6	2.2	0.14	9.0	21	152	1,000	0.90	14
Diego Martin	4	15	5.7	1.8	0.13	8.0	14	51	1,000	1.19	18
Sta. Cruz, old	4	19	5.6	2.9	0.18	9.3	40	136	1,760	1.23	19
Sta. Cruz, new	7	18	5.9	2.1	0.18	7.1	23	102	—	0.78	12
Maracas	4	24	6.1	3.1	0.23	8.2	14	94	2,420	1.07	16
Caura	4	19	5.2	2.5	0.17	8.4	13	91	920	1.68	25
Arima	4	28	5.6	2.6	0.20	7.5	23	186	1,190	1.23	19
Aripo	1	24	5.5	2.3	0.21	6.4	11	82	870	1.32	20
(C) CENTRAL RANGE, NORTH-EASTERN FLANKS.											
Spring	3	42	4.9	3.7	0.27	7.9	20	140	490	2.47	37
Perseverance	5	39	5.3	4.3	0.31	8.1	15	244	1,570	1.81	27

(2) They are only slightly acidic at the Experiment Station, markedly acidic in the Northern Range area, and very highly acidic in the two Central Range areas.

(3) Their contents of organic matter are fairly high.

(4) Total nitrogen is very high in amount.

The average total nitrogen contents for 127 examples of California Citrus soils range from 0.022 to 0.067 per cent., and for Rhodesia Citrus soils from 0.05 to 0.13 per cent., whereas the average for Trinidad Northern Range soils is 0.17 per cent., and 0.29 per cent. for Central Range soils. The high nitrogen content of Trinidad soils is doubtless due to the fact that they were recently under cacao and leguminous Immortel shade trees. The accumulated leaf and root debris has not yet been lost by erosion and leaching, since most of the cultivations are young.

(5) Carbon-Nitrogen Ratios are fairly high, indicating incomplete breakdown and humification of the organic debris.

(6) Available phosphate contents are very low (20 p.p.m.).

(7) Available potash contents are variable, but generally only medium in amount.

The better grapefruit soils appear to contain the greater amounts of available potash. Hill-slope grapefruit soils of the Northern Range are usually somewhat richer in available potash than corresponding valley-bottom soils.

(8) Available lime is low in amount, except the St. Augustine soil, which was formerly under sugar-cane that had been treated with large dressings of ground limestone.

(9) On the whole, the St. Augustine soil seems to be the most suited to the grapefruit crop.

The grapefruit soils of Trinidad are thus characterised by (*a*) an apparently unsatisfactory lime status, (*b*) very low available phosphate contents, (*c*) usually inadequate available potash contents, and (*d*) very high total nitrogen contents.

Present Manurial Indications.

In order to improve the nutrient status of the soils, judicious *liming* appears to be an important need, whilst the addition of artificial nitrogenous manures, nitrogenous organic matter and leguminous cover crops in large quantities would seem, at the present juncture, to be perhaps unwarranted. Phosphate manuring may be necessary, although grapefruit is considered by many authorities not to require heavy applications of phosphate. The phosphate question is puzzling, and has not yet been completely investigated in Trinidad. Potash manuring seems to be necessary in most instances, although the haphazard and excessive use of potassic manures on *lime-deficient* soils may be both harmful and wasteful.

Perhaps the most important practical result of correcting lime deficiencies in acidic grapefruit soils may be the *saving in potash manure* necessary for the greatest production in yield of fruit of high quality. Whilst this assumption is not at present amenable of direct proof in Trinidad, further work may indicate how far its significance applies to commercial grapefruit growing. The fact that the lime and potash contents of grapefruit leaves bear a very high degree of negative correlation one with the other suggests than an increase in leaf lime content (which chemical analysis shows may be

induced by soil liming) might suppress the excessive uptake of potash and its passage into the leaf; this may mean that the supply of potash in the soil need not be so abundant when adequate lime is available to the growing tree.

The significance in grapefruit cultivation in Trinidad of minor elements, such as manganese, copper and zinc, has not yet been examined. Samples of leaf material are being spectroscopically tested for these elements in England.

Future Manurial Indications.

No doubt as time goes on, and soil erosion, surface washing, continued leaching and heavy cropping have exerted their drastic effects, the need for manurial applications will be more and more evident. In due course, the *nitrogen* reserves of the soil doubtless will have to be augmented, but the stage at which this may become necessary is at present unknown, at least in most instances.

The subsoil reserves of nutrients (layers below top three or six inches) appear to be relatively poor in the majority of the grapefruit areas in Trinidad, as is clearly indicated by soil profile studies. The main problem of the future will be to maintain soil fertility rather than to build it up or to increase it. Manuring may be ineffective or wasteful where drainage and soil moisture conditions are unsatisfactory, and where over exposure to wind and diseases have lessened the response of the trees to manurial treatment. It is probably a mistake continuously to clean-weed the ground around grapefruit trees, for weeds in the orchard have their uses, in that they may increase the availability of potash and of iron, and may lower the ratio of nitrogen to potash. At the onset of dry weather, weeds should be cut back to reduce loss of soil moisture, and the vegetable matter piled up near the bases of the trees.

Lime Requirement.

In the last two columns of Table II, lime requirement values are presented; (*a*) in tons of finely-ground limestone per acre (surface 3-inch layer) of soil, and (*b*) in pounds per tree. They were determined in the laboratory by tested methods. The standard adopted for adequate lime status in grapefruit soils is 65 per cent. of saturation of the soil by lime (absorbed, exchangeable, or surface-combined calcium), provided the soil is not rendered unduly alkaline by the liming process. There is little danger of this, if the amounts suggested are strictly adhered to. The data are summarised from detailed results for 59 soils set out in a report on lime requirements (Sixth Report).

The quantities per tree are based on the assumption that the ground limestone is to be applied within a ring of dimensions ten feet and $2\frac{1}{2}$ feet radii, with the tree trunk as centre. The conversion factor is 15.2 (L.R. lb. per tree = L.R. tons per acre × 15.2). Other factors could be derived if adjustments in the dimensions of the ring to suit the size of tree are considered necessary.

The lime requirements of the grapefruit soils of Trinidad so far examined vary from 8 to 33 lb. per tree (average, 15 lb.), for the westerly valleys of the Northern Range, but they are nearer 22 lb. per tree for easterly valleys (Caura, Arima, Aripo). For Central Range soils, the lime requirements vary from 6 to 60 lb. per tree (average, 31 lb.). The soils here are heavy (Brasso Clay or Alluvium) and highly acidic, except the newly developed lands near Spring, which are sandy, but very highly acidic. The lime requirement of the St. Augustine soil is almost negligible.

The ground limestone recommended for application to grapefruit cultivations should be finely pulverised, so that between 55 and 65 per cent. passes a 100 to the linear inch sieve, and all passes a 10-mesh sieve. Such limestone would cost about six dollars ($6.00) a ton in Trinidad Assuming this price, the cost of an average dressing of 18 lb. per tree would be about 4.8 cents, *plus* the cost of application, bringing the total to say $5\frac{1}{2}$ cents a tree, or $2.60 an acre of 48 trees which is not exorbitant.

It is still questionable, however, whether planters would be prepared to expend money on dressings of limestone, or whether they would consider some of the recommended dressings to be really necessary, in view of the satisfactory results already obtained in Trinidad grapefruit cultivations. The point deserves careful testing by controlled field experiments, laid down along modern lines, although valuable data and observations might be obtained by liming selected trees or rows in the orchard, and keeping notes and records of appearance, behaviour and yield of both lime-treated and untreated trees.

(B) Leaf Investigations.

Most of the grapefruit fields in Trinidad have been treated more or less arbitrarily, though not always consistently and discriminately, with various artificial mineral manures, and occasionally, with organic manures. Different manurial mixtures have been favoured by different planters, but no reliable outside information regarding the best means of manuring grapefruit under the climatic and soil conditions obtaining in Trinidad is available for the guidance of growers.

(I) The St. Augustine Manurial Experiment.

In order to provide such information, a comprehensive large-scale manurial experiment on Marsh Seedless Grapefruit was inaugurated in July, 1932, at the St. Augustine Experiment Station, by Officers of the Department of Agriculture. The average rainfall at the Station is about 60 inches a year, which is somewhat low. The layout has been described by R. O. Williams in *Tropical Agriculture*, Vol. IX, 1932, pp. 301 to 306. There are two identical blocks, each containing 32 differently-treated plots, set out in Latin Square arrangement. The main object of the experiment is to discover the best combination of ammonium sulphate, superphosphate and sulphate of potash, both in the absence and in the presence of pen manure.

An attempt was made in September, 1934, to identify the best manurial treatment for Marsh Seedless Grapefruit budded on to Sour Orange stock, under the conditions of this experiment, by chemically analysing representative leaf material collected from the different plots, and comparing the derived nutrient ratios for leaf-ash components with those for "standard" California material, whose analyses have been published in the literature of Citrus. This was the only possible procedure, since no long-established, entirely satisfactory grapefruit cultivations that could be regarded as ideal for purposes of comparison exist at the present time in Trinidad.

The results of leaf-ash analysis for one of the blocks (Block A (West)) of the St. Augustine manurial experiment are set out in Table III, together with derived nutrient ratios, and comparable "standard" data for California material. The results obtained for leaf material collected from the other block are essentially similar, and therefore need not here be considered. A complete account of the whole of the work forms the Fourth Report on Grapefruit Investigations.

Conclusions from Leaf Analyses; St. Augustine Grapefruit.

(1) The simplest treatment which brings leaf-ash composition, and particularly the nutrient ratios, nearest to those of the "Standard" is the *single nitrogen* plus *potash* treatment (No. 9).

(2) Other treatments which appear also suitably to have modified the nutrient ratios are, *pen manure* plus *single nitrogen* plus *phosphate* (No. 15), and the full treatment, *pen manure* plus *single nitrogen* plus *phosphate* plus *potash* (No. 17). There is not much to choose between these three.

(3) Evidently potash, together with a certain amount of nitrogen, is best suited to the grapefruit tree, strictly under the conditions imposed by the soil of Block A of the Experiment Station, and under the climatic conditions that have obtained there during the past three years.

Pen manure appears to have acted in this experiment as if it contained a small amount of nitrogen and a large amount of potash. Consideration of its composition, and the degree of availability of these two ingredients, fully supports this contention; the arguments are set out in detail in the Fourth Report.

Table III.

CHEMICAL COMPOSITION OF LEAF-ASH OF GRAPEFRUIT GROWN ON DIFFERENTLY-TREATED PLOTS. ST. AUGUSTINE MANURIAL EXPERIMENT. (DATA FOR BLOCK A (WEST).)

Values for Magnesia (MgO) omitted.

	Ash per cent. Dry Matter.	Composition of Leaf-Ash.				Nutrient Ratios.			
		N	P_2O_5	K_2O	CaO	N / P_2O_5	N / K_2O	K_2O / P_2O_5	CaO / K_2O
		Percentage of Total Ash.							
"STANDARD"									
1. California Citrus	17.7	13.5	2.1	7.2	48.4	6.4	1.9	3.4	6.7
2. Control Plots	12.5	17.5	6.6	7.4	42.7	2.6	2.4	1.1	5.8
3. Nitrogen (N)	13.0	22.8	3.1	3.5	44.1	7.4	6.4	1.1	12.4
4. Double Nitr. (2N)	13.1	25.1	3.6	4.2	47.3	6.9	6.0	1.2	11.2
5. Phosphate (P)	13.5	18.0	6.2	5.2	44.5	2.9	3.5	0.8	8.6
6. Potash (K)	13.5	16.0	6.0	16.0	37.5	2.6	1.0	2.6	2.3
7. N + P	11.9	29.5	4.4	2.9	47.2	6.7	10.0	0.7	15.9
8. 2N + P	13.7	23.6	3.6	3.1	47.5	6.6	7.6	0.9	15.2
9. N + K*....	14.3	17.1	3.0	7.9	45.1	5.7	2.2	2.6	5.7
10. 2N + K	13.1	22.2	4.2	7.5	44.4	5.3	3.0	1.8	5.9
11. P + K	15.8	15.0	6.7	12.4	33.6	2.2	1.2	1.8	2.7
12. N + P+K	12.2	21.8	4.1	7.4	43.5	5.3	2.9	1.8	5.9
13. 2N + P+K	11.8	26.1	4.3	10.0	42.0	6.0	2.6	2.3	4.2
14. P.M. + N	11.8	24.2	4.8	16.4	38.6	5.1	1.5	3.4	2.4
15. P.M. + N+P*	12.7	20.1	4.3	10.6	41.8	4.6	1.9	2.4	3.9
16. P.M. + N+K	11.7	23.6	4.2	14.8	41.0	5.6	1.6	3.5	2.8
17. P.M. + N+P+K*	12.9	20.9	4.3	12.7	41.2	4.8	1.6	2.9	3.3

* Best combinations of manures in effect on nutrient ratios.

Hence the two best pen manure treatments appear nutritionally to resemble $1\frac{1}{2}N+P+K$ (No. 15), and $1\frac{1}{2}N+P+2K$ (No. 17) respectively, both of which supply considerable nitrogen, together with potash in good quantity. Probably additional potash may have been still more beneficial, provided it were accompanied by a suitable amount of nitrogen.

(4) The need of additional nitrogen in this block of the St. Augustine Experiment is apparently associated with the somewhat relatively low content of total nitrogen (0.15 per cent.; surface 3-ins., and 0.13 per cent., second 3-ins., layer) and low C/N ratio, as compared with Trinidad grapefruit soils in general. It is not accurately known what proportionate amount of the total nitrogen is readily available to the grapefruit tree.

(5) The various complex and inter-related effects of the different manurial treatments on the composition and nutrient ratios of the leaf-ash are clearly revealed by the analytical data. They need not here be considered in detail, but the following chief features may be indicated,

(*i*) *Nitrogen* in leaf is increased by nitrogenous manure, but decreased by potash and phosphate manures.

(*ii*) *Phosphate* in leaf is decreased by all treatments for reasons that are not yet clear.

(*iii*) *Potash* in leaf is very greatly increased by potash manure and pen manure, but decreased by nitrogenous and phosphatic manures. Heavy nitrogenous manuring, however, tends somewhat to increase potash content of leaf.

(*iv*) *Lime* in leaf is greatly decreased by potash manure, but increased especially by nitrogenous manure, and by phosphatic manure.

(*v*) Marked *reciprocal* relationships are shown between (*a*) potash and lime, (*b*) potash and nitrogen, and (*c*) nitrogen and phosphate contents of the leaf.

(*vi*) Slight direct or *positive* relationship is shown by nitrogen and potash contents for heavy dressings of nitrogenous manures.

(6) *Pen manure* appears to have acted mainly as a supplier of nitrogen and (especially) potash (see (3) above), but an important effect appears to have been a general levelling of nutrient contents of leaf. How far other effects (such as iron-nutrition; "auximone" nutrition; nutrient fixation or "adsorption"; solubilising action on soil minerals, and improvement of water and air relations) have operated for the benefit or detriment of the grapefruit tree (rate of growth, flowering, fruiting, fruit-quality, disease resistance, &c.) can only be assessed by future observations and measurements.

Growth Rate Measurements at St. Augustine.

Striking confirmation of the conclusions reached from leaf analysis of grapefruit grown at the St. Augustine Experiment Station, described in the last section, is afforded by the records of growth-rate measurements kept by E. J. Gregory, Manager. The growth records have recently been published (typescript report) by R. O. Williams and himself. They indicate that the best manurial treatment for increasing the growth of young trees at St. Augustine is *pen manure* plus *nitrogen* plus *phosphate*, which is one of the "best" mixtures deduced from the leaf analysis data. Two other pen-manure treatments come next in their list, followed closely by the *single nitrogen* plus *potash* treatment, which was also indicated by the leaf analytical data as one of the best, if not the best, of the manurial mixtures. There is a close similarity in the order of effectiveness of the different manurial treatments on growth-rate and on improvement of nutrient ratios in the leaf.

Nutrient Balance and Total Quantity of Manure.

It must not be assumed that the only important result of correct manuring is an adjustment of nutrient ratios in the leaf; obviously the relative total amounts of mineral nutrient substances that are supplied to and taken up by the tree, in accordance with its age and stage of development, may also be very important.

(*i*) Thus, the nutrient ratios for the Control Plot (No Manure) are quite near to those of the Standard and the best manurial mixtures, yet the growth-rate of the Control Plot trees was lowest of all.

(*ii*) The pen manure treatments that gave best results conveyed the greatest quantities of nutrient substances to the soil, particularly nitrogen and potash.

Nevertheless, the simple mixture of single nitrogen and potash gave high growth-rate, even though the total amount of nutrients supplied was not exceptionally large. Hence the *balance of nutrients* in a manure is at least as important as the total amount of manure, and *a properly-balanced mixture conveys the essential ingredients in smallest effective quantities, and therefore at least relative cost.*

(II) Typical Grapefruit fields of Trinidad.

Representative leaf material has also been analysed for grapefruit trees growing in different areas in Trinidad, with the object of comparing the results with those obtained at St. Augustine, as described in the last section. Summarised analytical data are presented in Table IV. It should be particularly noted that most of the trees whose foliage was analysed have been more or less heavily treated with arbitrary mixtures of different combinations of artificial manures for varying periods of time. The trees have different ages, but this does not necessarily introduce discrepancies, because it is believed that only the age of the leaf-flush matters, and not that of the tree itself (Investigations in California).

Conclusions for Leaf Analyses; Trinidad Grapefruit.

(1) Manured grapefruit trees, typical of most of the areas in Trinidad, yield leaf material relatively rich in *nitrogen*, as compared with the California "standard", and with the average for the best three treatments at St. Augustine. This may be the result of the initially-high nitrogen content of the soil, coupled with nitrogenous manuring that has been practised in some instances.

(2) *Phosphate* contents, on the other hand, are not exceptionally high, but their significance has not yet been fully investigated, and they need not here be further considered.

(3) *Potash* leaf-contents are extremely high, possibly due, in many cases, to excessive potash manuring on lime-deficient soils.

(4) *Lime* contents are generally very low (with one or two exceptions), as would be expected from the known low contents of available soil lime.

(5) *Nutrient Ratios* are unsatisfactory, especially the important nitrogen/potash ratio, which is generally very low, in spite of high leaf nitrogen contents.

Evidently the chief chemical feature of the leaf material of grapefruit trees in Trinidad is its exceptionally high content of potash, and its low content of lime. Since these two entities show marked reciprocal relationships, it would seem that the easiest, cheapest and quickest way to correct this unsatisfactory condition is carefully-controlled liming. This agrees with the main conclusion drawn from the soil investigations.

Suggestions for Future Investigations.

(1) Until the lime status of the grapefruit soils has been improved by correct liming, the continued use of arbitrary mixtures of artificial manures in the grapefruit orchards of Trinidad would appear to be unwarranted, if not wasteful or even harmful. No useful purpose would be served, therefore, by continuing the examination of leaf material, except in connection with the important St. Augustine experiment. On the other hand, routine determination of the lime requirements of grapefruit soils not yet investigated, and of soils intended for grapefruit cultivation, might be helpful to planters. An extension of the detailed soil survey of Trinidad would be advantageous for advisory purposes.

(2) The puzzling questions of phosphate fixation by soil, and phosphate uptake by the grapefruit tree, considered in relation to composition of leaf, and (later) to quality of fruit, are still being studied, and results may be forthcoming in due course.

(3) How far manurial responses are affected by differing rainfall, soil-moisture conditions, &c., cannot be gauged until the lime status and general fertility of the grapefruit soils have been adjusted to uniform conditions. The value of the St. Augustine Manurial Experiment would be seriously diminished unless immediate steps be taken to bring the lime status of estate soils to the same level as that which obtains in the St. Augustine experimental plots. The only other alternatives would be to inaugurate a similar

Table IV.

CHEMICAL COMPOSITION OF LEAF-ASH OF GRAPEFRUIT GROWN IN TYPICAL AREAS IN TRINIDAD.
(SUMMARISED DATA FROM THIRD REPORT.)
Values for Magnesia (MgO) omitted.

	Ash per cent. Dry Matter.	Composition of Leaf-Ash. Percentage of Total Ash.				Nutrient Ratios.			
		N	P_2O_5	K_2O	CaO	$\frac{N}{P_2O_5}$	$\frac{N}{K_2O}$	$\frac{K_2O}{P_2O_5}$	$\frac{CaO}{K_2O}$
"STANDARD"									
1. California Citrus	17.7	13.5	2.1	7.2	48.4	6.4	1.9	3.4	6.7
2. St. Augustine (Best 3)	13.3	19.4	3.9	10.4	42.7	5.0	1.9	2.7	4.1
(A) NORTHERN RANGE VALLEYS.									
3. Tucker (Maqueripe) (12) ..	12.6	21.9	3.8	19.7	36.1	5.8	1.2	5.2	1.9
4. Diego Martin (River) (4)	10.0	27.4	5.7	22.6	31.9	4.9	1.3	5.1	1.5
5. Sta. Cruz (Soledad) (3)	10.5	24.4	3.8	14.2	39.7	6.4	1.8	4.0	3.0
6. Caura (Arcadia) (1)	11.7	17.4	3.0	19.0	36.6	5.8	0.9	6.3	1.9
7. Arima (Torrecilla) (1)	15.8	17.1	3.8	12.2	41.9	4.5	1.4	3.2	3.4
8. Aripo (Naranjo) (2)	13.6	16.8	2.7	16.0	38.7	6.1	1.0	6.1	2.3
(B) CENTRAL RANGE.									
9. Spring (1)	9.4	29.3	4.3	22.0	30.6	6.8	1.3	5.1	1.4
10. Perseverance (3)	9.4	25.7	4.0	23.4	32.6	6.5	1.1	6.0	1.4
Means of All (Weighted)	11.6	23.2	4.1	19.8	35.5	5.7	1.2	4.8	1.8

Note.—The figures in brackets after the name of the area indicate the number of fields whose grapefruit leaves were sampled for chemical analysis, *i.e.*, 27 in all.

experiment on acidic sandy soil in one of the Northern Range Valleys, or to lay down a definite liming experiment with suitable control (unlimed) plots, in order to test critically the effect of lime on the utilisation of nutrients by the grapefruit tree.

Such experiments would have considerable practical value in connection with the supposition stressed in this article, namely, that the grapefruit trees, and Citrus trees in general, are calcicolous or "lime-loving" plants, that thrive best in soils containing relatively abundant supplies of available lime. Furthermore, a liming experiment would furnish reliable data concerning the conservation of potash by the deliberate addition to the soil of suitable dressings of ground limestone.

(C) Fruit Investigations.

A limited number of chemical analyses have been performed in order (*a*) to compare the measurable attributes and chemical composition of grapefruits produced in Trinidad with those of fruits produced in other countries; (*b*) to compare fruits grown on neutral or slightly alkaline, lime-rich soil with fruits grown on acidic soil in Trinidad; (*c*) to compare different commercial grades of fruit as turned out at the Packing Shed in Port-of-Spain.

For these purposes, eight crates of grapefruit were procured from the Packing Shed on 27th February, 1935. Four of the crates contained fruits picked from trees growing at

Table V.

COMPOSITION OF GRAPEFRUITS.

	Trinidad Grapefruit.				Foreign Fruit.		
	El Quemado.		Maqueripe.				
	Choice.	Culls.	Choice.	Culls.	Florida. (7)	Puerto Rico. (6)	Texas. (8)
(A) Whole Fruit.							
1. Average Weight per fruit (gm)	435	437	384	404	....	511	466
2. Average Density (gm/c.c.)	0.943	1.043	0.993	0.946	....	....	....
3. Rind and Albedo, per cent.	22.9	23.8	20.5	25.6	....	....	....
4. Juice and Pulp, per cent.	76.8	75.9	79.2	74.2	....	68.9	75.4
5. Total Dry Matter, per cent.	12.0	14.5	13.8	14.5	....	....	14.1
6. Total Ash, per cent.	0.40	0.54	0.44	0.48	....	....	....
(B) Grapefruit Juice.							
7. Brix Degree (Total Solids)	9.10	8.60	9.23	8.90	....	8.07	9.80
8. Degree of Acidity (pH)	3.25	3.26	3.10	3.27	....	....	3.19
9. Total Ash, per cent.	0.18	0.24	0.20	0.22	0.54	....	0.22
10. Total Sugars, per cent.	7.3	6.5	6.9	6.8	6.7	4.8	6.3
11. Reducing Sugars, per cent.	4.9	4.8	5.1	5.0	....	3.1	3.5
12. Citric acid, per cent.	1.01	0.96	1.11	1.04	1.40	1.13	1.19
13. Ratio, Brix/Acid	9.0	9.0	8.3	8.5	....	7.1	8.3
14. Ratio, Sugar/Acid	7.2	6.7	6.2	6.5	4.8	4.2	5.3
(C) Rind-Ash.							
15. Ash in Dry Matter (per cent.)	4.1	4.2	3.8	3.7	....	....	....
16. Nitrogen (N) per cent. Ash	14.6	18.3	20.1	23.9	....	....	....
17. Phosphate (P_2O_5) per cent. Ash	3.8	4.6	3.7	4.6	....	....	....
18. Potash (K_2O) per cent. Ash	23.0	30.6	34.2	35.7	....	....	....
19. Lime (CaO) per cent. Ash	35.9	29.2	23.4	25.1	....	....	....
20. Ratio, N/P_2O_5	3.8	4.0	5.3	5.1	....	....	....
21. Ratio, N/K_2O	0.6	0.6	0.6	0.7	....	....	....
22. Ratio, K_2O/P_2O_5	6.0	6.6	9.1	7.7	....	....	....
23. Ratio, K_2O/CaO	0.6	1.0	1.5	1.4	....	....	....
(D) Juice-Ash.							
24. Ash in Dry Matter (per cent.)	2.3	3.1	2.5	2.8	....	....	2.3
25. Nitrogen (N) per cent. Ash	23.4	23.9	25.6	27.1	....	....	35.6
26. Phosphate (P_2O_5) per cent. Ash	15.2	12.9	11.5	12.5	....	....	....
27. Potash (K_2O) per cent. Ash	49.2	48.4	53.3	52.7	....	....	....
28. Lime (CaO) per cent. Ash	10.1	6.7	5.5	6.1	....	....	....
29. Ratio, N/P_2O_5	1.5	1.8	2.2	2.2	....	....	....
30. Ratio, N/K_2O	0.5	0.5	0.5	0.5	....	....	....
31. Ratio, K_2O/P_2O_5	3.2	3.7	4.7	4.3	....	....	....
32. Ratio, K_2O/CaO	4.8	7.2	9.9	8.8	....	....	....

El Quemado Estate, on the north-central flanks of the Central Range, where the soil is rich in available lime and neutral or slightly alkaline in reaction,and four contained fruits from Maqueripe Estate, Tucker Valley, west Northern Range, where the soil is highly acidic. A cursory examination of the soil at El Quemado, and a consultation of a recent accurate geological map of the district, indicate that the soil-type is Brasso Clay intercalated with reef limestone (Machapoorie Limestone) that forms the cores of a series of low steep hills with which the district abounds.

Each of the four crates (about 30 fruits) of each category, represented a different commercial grade of fruit, namely, Choice, Standard, Third Grade and Culls. Grading is based mainly on shape, texture and discoloration. No obvious relationship between "quality", as defined by these terms, and chemical composition, would be expected, but it was thought interesting to examine this question as part of the general problem.

The presentation of the details of this fruit investigation, and the tabulation and discussion of the results obtained, are reserved for full treatment in a future report (Seventh Report). Some results are set out in Table V. Data for choice fruits and culls only are included; those for standard and third-grade, on the whole, are intermediate between these extremes.

Conclusions from Fruit Analyses.

(1) *Trinidad* versus *Foreign Grapefruit**.

The proportionate amount of juice and pulp is somewhat higher in the local fruit, and the proportion of rind and albedo correspondingly lower. Total sugar is higher, and citric acid lower, so that the sugar-acid ratio is very high for the Trinidad fruit, indicating its exceptionally good quality.

(2) *Lime-land Fruit* versus *Acidic-land Fruit.*

(*i*) There is little difference between the two sorts as regards proportion of juice and pulp, and rind and albedo.

(*ii*) Lime-land juice has a higher sugar-acid ratio than acidic-land juice, indicating better fruit quality.

(*iii*) The *rind* of lime-land fruit is much less rich in nitrogen and potash, but slightly richer in phosphate, and much richer in lime than the rind of acidic-land fruit. The ratios between these pairs of entities clearly distinguish the fruits grown on the two contrasted sorts of soil.

(*iv*) The *juice* of lime-land fruit shows very similar differences from that of the acidic-land fruit as are shown by the rind, namely, lower nitrogen and potash contents, but higher phosphate and lime contents. These differences are clearly reflected in the nutrient ratio values.

Evidently, high nitrogen content (and perhaps also high potash content), both of rind and juice, indicate somewhat inferior quality, and seem to be associated with relatively low sugar content and low sugar-acid ratio. These features have been previously reported by other investigators. They may be a direct result of over-manuring with nitrogenous manure and potash manure, or of an initially high content of nitrogen in the soil. High nitrogen content would be expected to be enhanced or aggravated by wet weather, which is believed to increase the "duty" of soil nitrogen. Perhaps the tendency for grapefruit trees in Trinidad to produce coarse fruits of lower quality during exceptionally wet seasons may be traced to enhanced nitrogen uptake.

(3) *Choice Fruits* versus *Culls.*

(*i*) Choice fruit seems to contain a slightly higher proportion of juice and pulp than culls.

(*ii*) It has a greater sugar content, and a greater acid content, and the sugar-acid ratio tends to be higher.

(*iii*) The *rind* of choice fruit appears to possess lower nitrogen, phosphate and potash contents, but higher lime content than the rind of cull fruit. The differences may not be significant, however, and the nutrient ratios do not differ consistently.

* *Note.*—It has not been possible so far to procure strictly comparable data for the composition of the *ash* of grapefruit grown in countries outside Trinidad, but the following figures roughly indicate differences that may be characteristic.

Relative amounts of Nutrients in Whole Fruits.	N	P_2O_5	K_2O	CaO
(A) GRAPEFRUIT ....Puerto Rico (Duncan) F. A. L. Dominguez (6)	2.0	1.0	3.3	?
Florida (Pomello) H. H. Hume (7)	2.2	1.0	4.7	?
Trinidad (Marsh Var.) G. Rodriguez				
(*a*) Lime-land fruit	2.5	1.0	4.3	2.6
(*b*) Acidic-land fruit	3.5	1.0	5.2	2.6
(B) ORANGE ....Florida; E. L. Lord (3)	1.6	1.0	6.0	2.7
California; E. L. Lord (3)	3.4	1.0	4.0	2.2

The values indicate the relatively high nitrogen contents of Trinidad grapefruit.

(*iv*) The *juice* of choice fruit differs from that of culls in its lower nitrogen content (as in the case of the rind), but, unlike the rind, its potash content is higher, whilst phosphate and lime contents show inconsistent differences. The ratio values are also inconsistent.

The fact that nitrogen content of culls, both rind and juice, is higher than that of choice fruit again suggests that excessive soil nitrogen, or over-manuring with nitrogenous substances, may lower the quality of grapefruit, not only in its effect on fruit composition, but also on the internal structure or anatomy of the fruit, which may decide rind thickness and juiciness of fruit.

Summary.

(A) Soil Investigations.

(1) Grapefruit is grown in Trinidad under natural rainfall conditions on soils that are sandy and acidic (Northern Range Valleys), or clayey and highly acidic (Central Range). The soil profile is markedly stratified; most of the organic matter and nutrients occur in the surface layer (top three to six inches); root distribution is mainly confined to this shallow surface soil.

(2) *Calcium* appears to be a specially important element for grapefruit and Citrus generally. Most of the grapefruit soils of Trinidad appear to be deficient in calcium (available lime). Lime requirements needed for 65 per cent. saturation have been determined for representative examples.

(3) *Nitrogen* is naturally abundant in the grapefruit soils of Trinidad, many of which were recently under cacao.

(4) Available *phosphate* is very deficient, and available *potash* variable, but generally medium in amount.

(5) Recommendations for manuring grapefruit, based on these data, are made for present and future needs. Suitable liming may be the first requirement.

(B) Leaf Investigations.

(1) Chemical analyses were made of leaf material obtained from the plots of a large manurial experiment on three-years' old grapefruit at the St. Augustine Experiment Station, in an attempt to identify the best manurial treatments by comparison of nutrient ratios with those for Citrus leaf material analysed in California.

(2) The "best" mixtures identified by this means nearly coincide with those identified by measurements of growth rates. Potash, together with nitrogen in appropriate amount, have given best results on growth of young grapefruit in the soil of the Station, which has been limed.

(3) The nutrient effects of pen-manure in this experiment have been roughly assessed. Pen-manure has acted like a high potash low nitrogen manure.

(4) Various interactions between nutrients in leaf have been revealed and discussed. Potash and lime and potash and nitrogen of leaf show close reciprocal relationships.

(5) Chemical analyses have also been made of leaf material obtained from typical manured grapefruit fields in Trinidad. The results indicate a general sufficiency or excess of nitrogen and potash, but a marked deficiency of calcium and phosphate, suggesting the need for lime, and caution particularly in the use of nitrogenous manures.

(C) Fruit Investigations.

(1) Chemical analyses have been made of typical grapefruits obtained from (A) a lime-land estate, and (B) an acidic-land estate in Trinidad. Four commercial grades belonging to each category were separately analysed.

(2) Trinidad grapefruit contains a relatively high proportion of juice and pulp, and a very high sugar-acid ratio, as compared with certain published analyses of fruit grown in Florida, Puerto Rico and Texas. Its quality thus appears to be good.

(3) Lime-land grapefruits have a higher sugar-acid ratio than acidic-land fruits.

(4) Lime-land grapefruit rind and juice contain relatively less nitrogen and potash, but more lime and phosphate than acidic-land rind and juice.

(5) Choice-grade grapefruits appear to contain slightly more sugar and acid, with a higher sugar-acid ratio, than cull fruits. The rind and juice of choice fruits appear to contain slightly less nitrogen than cull fruits, but mineral components do not differ significantly.

(6) High nitrogen content seems to be associated with low quality in grapefruit; it especially characterises acidic-land fruit and cull fruit in Trinidad. Excessively wet seasons may increase nitrogen content of fruit, and thus lower the quality, by enhancing the availability and uptake of soil nitrogen.

Acknowledgments.

Co-operation in the collection of soil and leaf samples at the St. Augustine Station was willingly given by Mr. E. J. Gregory. Information on grapefruit areas and grading was readily imparted by Mr. C. B. Anderson, Manager and Secretary of the Citrus Growers' Association, by Mr. E. J. Wortley, Director, and by Mr. R. O. Williams, Assistant Director of Agriculture. To these gentlemen, the writer wishes to convey his best thanks, and also to certain planters, notably Mr. H. Rapsey and Mr. W. S. E. Barnardo, and to several estates managers and overseers, who have helped in the collection of samples and the compilation of information.

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(1) Grapefruit Culture in the British West Indies and British Honduras.—H. Clark Powell, *E.M.B.* 13, Dec., 1928.

(2) (a) Effect of Sodium Chlorid and Calcium Chlorid upon Growth and Composition of Young Orange Trees.—H. S. Reed, and A. R. C. Haas, *Univ. Calif. Agric. Expt. Sta.*, Tech. Paper 4, 1923, p. 132.

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(6) Changes Wrought in Grapefruit in the Process of Maturation.—F. A. Lopez Dominiquez, *Journ. Dept. Agric. Porto Rico*, IV, 4, 1920, p. 93.

(7) Pomellos (Grapefruit) in Florida.—H. H. Hume, *Florida Agric. Expt. Sta.*, Bul. 58, 1901.

(8) Citrus Production in the Lower Rio Grande Valley of Texas.—H. F. Traube, and W. H. Friend, *Texas Agric. Expt. Sta.*, Bul. 419, 1930.

Appendix.

LIST OF REPORTS ON GRAPEFRUIT INVESTIGATIONS IN TRINIDAD.

(Presented in Typescript to the Citrus Growers' Association of Trinidad and Tobago, 1934-35). By F. Hardy and G. Rodriguez (Analyst).

(I) The Grapefruit Soils of Trinidad; (1) Typical Estates.—20th October, 1934.

(II) The Grapefruit Soils of Trinidad; (2) Soils of the St. Augustine Experiment Station.—28th December, 1934.

(III) Relationships between Composition of Grapefruit Leaf-Ash and Composition of Soil, as affected by Manuring in Trinidad; (1) Typical Estates.—6th February, 1935.

(VI) Relationships between Composition of Grapefruit Leaf-Ash and Composition of Soil; (2) St. Augustine Manurial Experiment. 1st March, 1935.

(V) Relationships between Composition of Grapefruit Leaf-Ash and Nutrient Status of Soil; (3) Phosphate Manurial Experiments on Two Estates in Northern Trinidad.—5th March, 1935.

(VI) The Grapefruit Soils of Trinidad; (3) Lime Status and Lime Requirements.—30th April, 1935.

(VII) Grapefruit Quality; Chemical Analysis of Grapefruit produced by two Contrasted Soil-types.—16th May, 1935.

A PROBABLE VECTOR OF CASSAVA MOSAIC IN SOUTHERN NIGERIA.

BY F. D. GOLDING, M.A., F.R.E.S.

IN 1929 the writer carried out a series of experiments with Aleurodidae to determine if they are vectors of Cassava Mosaic. The results of this study are described in a paper (1) in the 11th Annual Bulletin of the Nigerian Agricultural Department (in the press). No evidence was obtained that the Aleurodid which has recently been described by Corbett as *Bemisia nigeriensis*, sp. *novum* can operate as a vector of Cassava Mosaic.

Recently Storey (2) has shown that an unidentified species of Aleurodid is a vector of Cassava Mosaic in East Africa. Several thousands of the insects were released in a chamber containing cassava infected and uninfected with Mosaic with the result that all the plants rapidly became infected.

In his 1929 experiments the writer never introduced more than 55 adult Aleurodidae into any one cage and it was decided to repeat the investigation with larger numbers of the suspected vector.

On 6th March, 1935, two infected and two uninfected cuttings of Bitter Cassava, *Manihot utilissima*, were planted in each of two cages covered with muslin. Six days later all the plants had produced leaves; it was noticeable that the four healthy plants were more advanced than the four mosaicked plants.

Eight hundred and fourteen adult Aleurodids were collected from infected plants in the field and introduced into one of the cages on the following dates:—

21st March	22	29th March	26
22nd March	44	2nd April	75
23rd March	32	3rd April	72
25th March	47	4th April	43
26th March	66	5th April	78
27th March	87	6th April	67
28th March	81	8th April	74

On 8th April larvae were noticed on the leaves of both healthy and mosaicked plants.

On 9th April, Mosaic symptoms were noticed on two young leaves of one of the healthy plants. There was no sign of Mosaic on the leaves of either of the healthy plants in the control cage, which had been kept free from Aleurodidae.

It will be seen that an indication has been obtained that *Bemisia nigeriensis*, Corbett, can operate as a vector of Cassava Mosaic. It is hoped to carry out a series of cage experiments in the near future with the object of obtaining additional evidence of the transmission of Mosaic by this Aleurodid.

References.

(1) Golding, F. D. (1932).—Cassava Mosaic in Southern Nigeria. *11th Ann. Bull. Nigerian Agric. Dept.* (in press).

(2) Storey, H. H. (1934).—Report of the Plant Pathologist. *Rep. E. Agric. Res. Sta., Amani*, 6, 1933-34.

AN ENTOMOLOGICAL INVESTIGATION IN GRENADA.*

By J. G. Myers, Sc.D., F.R.E.S., F.Z.S.,
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I. Introduction and Acknowledgments.

The brief visit (of eight days) reported here arose out of a request for advice on certain banana pests in view of the development of an export banana industry. I was instructed to investigate the position with regard to the banana borer (*Cosmopolites sordidus*) and to enquire into the different species of borer (*Diatraea*) attacking sugar-cane, since that industry is also to be extended. Some attention could be paid to cacao pests if time permitted. The seven clear days available in the island were fully occupied with these enquiries. That a considerable portion of the island was covered in the time was due to the courtesy of His Honour the Administrator, Mr. J. M. Ellis, O.B.E., and the indefatigable energy of the Superintendent of Agriculture, Mr. W. O'Brien Donovan, and his colleague Mr. David Lang. One or other of these latter gentlemen accompanied me on every field excursion and gave me the full benefit of their extensive local knowledge. I am indebted for great hospitality to many members of the planting community throughout the island.

II. General Ecological Considerations.

A very valuable account of the geography, geology, soils vegetation of Grenada is contained in two recent reports by Professor F. Hardy and collaborators and by Captain R. C. Marshall (*see* list of references). Other general data are found in Myers (1931). It will be sufficient to recapitulate here that the island consists of 119 square miles of very mountainous (rising to 2,750 feet) volcanic country, well-watered, and with a generally high rainfall. The vegetation may be divided into a moist rain-forest type usually above 1,500 feet (rainfall over 100 inches), a dry belt (rainfall below 60 inches) at sea level, particularly in the south and north-east, consisting originally and now partially, of deciduous scrub, and an intervening middle belt (rainfall, 60 to 100 inches), of tropical rain-forest grading coastward into a semi-deciduous type, both now largely cultivated. The bulk of the cacao, nutmeg and banana cultivations lie in the middle belt, while the main sugar estates are situated within or on the borders of the dry belt. This distribution plays a very important rôle in the pest situation. Of equal significance is the relation between cultivated and unoccupied country. Approximately half the area is under permanent cultivation, but virgin forest occurs only in the mountain lands and on occasional ridges. The rest is waste-ground and various stages of second-growth periodically cleared for shifting peasant cultivation. Under these circumstances one would expect an abundance of insectivorous birds, but actually they are far from plentiful. The useful ground-lizards (*Ameiva aquilina*) have been more than decimated by the mongoose, and are now rare save within town limits. The equally beneficial leaf lizards (*Anolis richardii* everywhere, *Anolis gentilis* in the dry belt) are on the other hand, very plentiful. The position of the mongoose is peculiar. I saw none in seven days' field work, and planters were unanimous that it is decreasing rapidly. I am inclined to attribute this to two factors (1) the island swarms with small, underfed dogs, since no license is required outside town-limits, and these are said to hunt mongoose assiduously and (2) it is probable, from its failure to establish itself in Dominica, that a wet climate like that of Grenada is relatively unfavourable to mongoose.

Although Grenada is a typical member—the most southerly—of the Antillean chain—it was evidently connected with the mainland of South America up to a more recent date than any of its more northerly neighbours. To this fact it owes the presence of several South American (and Trinidad) mammals, birds, reptiles, amphibia, insects and plants which there reach their northern limit.

III. Banana Borer (*Cosmopolites sordidus*).

If there is one insect pest in the American tropics which is amenable to those methods of artificial control, notably hand-collecting, which are here so widely popular and so generally unsuccessful, at least against pests of native origin, it is the banana borer. It is an introduced insect, confined to a cultivated host (bananas and plantains) and devoid of parasites. Its means of dispersal, unless aided by the transport of infested planting-material, are moreover, comparatively slow. Under these circumstances we should expect the maximum results from direct control measures, of which the most important are plant selection, plantation hygiene and trapping.

When the planting of bananas was begun extensively in Grenada, about December, 1933, this was followed by many cases of severe infestation, necessitating supplying from 20 to 90 per cent. Such cases were widespread, and I was unable to associate them with any peculiar local conditions. There was, however, a distinct correlation with the source of supply of planting material. Where suckers had to be bought widely and extensively there was a greater infestation than where the planter was in the fortunate position of finding sufficient material already on the estate. This might be expected from the previous remarks regarding the slow spread of the pest when *not* aided by transport of suckers.

* Extracted from a Report recently submitted by Dr. Myers.

This heavy initial infestation was met by the planters with an energy and perseverance which command my respect, and later plantings and supplies were made with specially selected, largely borer-free material, while the initial borer population, not already destroyed in the rejected plants, was reduced by systematic trapping.

Partly, though as will be seen later, not entirely as a result of these measures, the present infestation throughout Grenada, at least in commercial plantings of Gros Michel bananas, is extraordinarily low.

The only heavy infestation (young plants, about 25 per cent.) which I saw, was evidently largely secondary. It was, on an otherwise clean estate, a small patch in an upland area (rainfall at least 150 inches), difficult to drain, partly waterlogged, the plants sickly, in at least one case examined dying from these causes and not from borer. Even here, supplying with clean suckers, and persistent trapping had greatly reduced the borer population and lowered the daily catches from 3,000 to 300 adult weevils per day.

In general the care and selection of planting material is now all that could be desired. "Bullheads" (*i.e.* stumps) if only slightly bored are trimmed of infested portions, while other inferior planting material is destroyed (*see* below). Plantation hygiene is much less widely practised, notably on estates where there was no initial infestation to stimulate it, and the low incidence of infestation prevailing in spite of this is evidence of peculiar conditions in Grenada, as compared, for instance with Jamaica and Haiti. Estates were visited where considerable areas of Gros Michel had been planted for the Swift Company (which failed), and where stools up to 14 years old were numerous; yet in these old stumps and stools I succeeded in finding one abandoned bore only after considerable search. Under such conditions in Jamaica banana borer would have been rampant. I am unable to explain this low infestation, which seems typical for Grenada. I should have been inclined to associate it with the fact that bananas almost throughout Grenada, are grown under the shade of cacao—often very dense while the suckers are at their most susceptible stage—and rarely in solid blocks; but at Pearl's I saw a splendid stand of Gros Michel, interplanted with cane certainly, but not shaded, and not even, as yet, adequately protected by wind-breaks, yet apparently free from infestation. Both here and on the old Swift plantings mentioned above, trapping was tried but no weevils were caught.

The test will undoubtedly come when the industry is more advanced, and when every estate has vast quantities of dead pseudostems and stumps to invite infestation. It seems unlikely that these will all share the practical immunity of the at present isolated old plantings, and the wisest course would be to carry out the strictest measures of hygiene and prevention from the outset.

Now as to the control measures already in operation or otherwise recommended, the most important is the selection of planting material. Infested suckers should be destroyed (*see* below). Several planters were treating suckers before planting—*e.g.*, with three per cent. sulphemulsol, but from the careful experiments of Mr. W. H. Edwards in Jamaica I am highly dubious of the efficacy of any such treatment. Rigorous selection alone would appear much safer and more satisfactory from every point of view.

Plantation hygiene involves the disposal of all infested or attractive material. The borer breeds freely in stumps and prostrate pseudostems left when the bunch is harvested. In Jamaica this material is sliced up finely with a cutlass and scattered on the ground to become dry and unattractive to the ovipositing weevils. Under the moist conditions prevailing in Grenada accentuated by the shade of the cacao, the necessary drying is in some places almost an impossibility. The best practice I saw was the collecting of the pseudostems, infested suckers &c., into a pen where stock were fed, the incorporation with manure being accelerated, on at least one estate, by the addition of Adco. On another estate the material was dumped into a shallow trench, where accumulated rain water drowned at least a majority of the borers, the whole being sterilised by weekly applications of crude oil. Whether any system which demands transport of the pseudostems will be economically practicable when extensive cropping begins, seems doubtful. In that case cutting up *in situ*, for drying (where possible) and (or) burying must be depended on.

Stumps should be cut low, and covered with a layer of soil to prevent access of the weevils. This is already done on several estates.

Finally, as to ways of trapping the adult weevils —there are two methods in general use. In one the cut stump is used as a trap, the horizontal butt being covered with a circular piece of the same stem. In the other a foot length of split pseudostem is laid on the ground—in some cases one beside every planted sucker. Traps should be examined once or twice a week according to the infestation. Neglected traps are a source of infestation, and those of the first type are particularly dangerous in this regard. Traps should be destroyed and replenished before they become putrid and thus no longer so attractive.

The whole question of control would be profoundly altered were the borer found breeding in any species of wild host-plant. From the viewpoint of botanical affinity, balisier (*Heliconia Bihai*) which is plentiful in second-growth rainforest and forms a wide belt between the virgin forest of the higher ridges and the upper level of the cacao cultivation, is the most probable host, but I have no evidence that it is ever attacked. Several planters had specifically searched it during clearing operations for banana planting but had found no trace. Mr. J. Branch found

an adult weevil at the base of a balisier growing among bananas, from which it had probably come. My own search was unsuccessful.

IV. Sugar-Cane Moth-Borers (*Diatraea* spp.)

The key to the status of sugar-cane pests in Grenada at present, and particularly to that of the moth-borers (*Diatraea* spp.) lies in the fact that practically all sugar-cane in Grenada, even on estates, is grown under peasant—and not estate—conditions, that is, in small, isolated patches surrounded by other crops, by wasteland, second-growth or forest. I have shown elsewhere that *Diatraea* especially is one of those pests which is much less prevalent in peasant cultivations than on estates. This is a question of the ecological balance; but planters usually prefer to explain it by saying that the borer "goes for" the best canes. The infestation by borers in Grenada at present is therefore no indication of what it may become when the estate industry now initiated, is fully developed. There are two species of *Diatraea* attacking cane in Grenada, the black-headed (*D. saccharalis*) and the yellow-headed (*D. canella*). *D. impersonatella*, which is the most destructive species in Trinidad, fortunately does not reach here, so that the position, so far as cane species are concerned, is closely similar to that of British Guiana, though the infestation is strikingly lower.

1. Infestation and Distribution.—The chief cane estates, as we have seen, lie in or on the margin of the southern dry belt. Cane was examined, however, wherever it occurred in the higher and wetter lands as well, and the infestation of representative randomised stools was analysed. It was not possible, under the present conditions in which cane is grown in Grenada, to find a plant field whenever an examination was made. More often than not there were only ratoons available, and frequently only one patch of these, and this had to be taken with whatever information could be gleaned as to name of variety and age of ratoon.

The samples, totalling 588 canes (with 5,488 joints) and shoots, showed 43.2 per cent. of the shoots killed by *Diatraea*, 42.3 per cent. of the stalks and 8.9 per cent. of the joints bored. This compares with a stalk infestation in British Guiana, of approximately 90 per cent. and a joint infestation of 20 per cent. corresponding to a loss in final sugar production of about 20 per cent. The present infestation in Grenada might therefore be taken to involve a loss of about eight to nine per cent., but there is not a simple arithmetical relation between infestation and loss, and the position is complicated by at least two other factors. One is that the infestation may be expected to increase when larger areas are planted under estate conditions. The second is that this estate development is to take place largely in the dry belt and its borders, and I have elsewhere shown that borer infestation, other things being equal, varies directly with the rainfall*. This is borne out in Grenada itself, so far as our small figures are adequate to the comparison, since the average joint infestation in the drier areas is about five per cent. and in the wetter areas about 20 per cent.

The high percentage of shoots killed by borer is associated with the abundance of the yellow-headed borer (*Diatraea canella*), a species which is usually much more frequent in young shoots than is the black-headed (*D. saccharalis*).

The chief peasant canes are White Transparent and Bourbon. B.H. 10/12 is being widely planted on the estates. Mr. E. Spencer had a first ratoon field of several varieties, in regular rows. Opportunity was taken to study difference in varietal susceptibility to infestation, by cutting out and examining two random-selected stools of each variety, totalling 671 joints. The percentage of joint infestation was as follows, Bourbon 20, B.H. 10/12, 24 and Caledonian Queen (cf. White Transparent) 21—no very striking difference, though it opposes the current belief that Bourbon is usually "riddled with borer as compared with other varieties". The plot of P.O.J. 2878 had been almost entirely cut out, as a result of froghopper infestation, and there was insufficient to yield a strictly comparable randomised sample, but one stool examined, yielded 105 joints, infested only 5 per cent.

2. Wild Host-Plants.—In any question of biological control the number and distribution of wild host-plants are of great importance. The following wild grasses were found infested with borers in Grenada:—

Eleusine indica, Pied poule, with *Diatraea saccharalis*.
Coix lacrima-jobi, Job's tears, with *Diatraea saccharalis*.
Valota insularis, with *Diatraea saccharalis*.
Leptochloa virgata, with *Diatraea saccharalis*.
Echinochloa polystachya, with *Diatraea saccharalis*.
Paspalum virgatum, with *Diatraea canella*.

These are all weed-grasses, save the *Echinochloa*, which is a water-grass frequent near the mouths of some of the rivers (specifically, River St. Johns, Beau Sejour River, Gouyave River—all on the leeward coast. I was unable to find it on the windward coast). The weed-grasses are frequent alike in cane-fields, cane-traces and on roadsides and waste land far from cane. Of the six grasses mentioned, only *Valota*, *Echinochloa* and *Paspalum virgatum*, are at all generally attacked. I regret that I was unable to obtain local names for these. The *Valota* was sometimes attacked to the extent of 60 per cent. of the stems; but this was on the edge of a cane-field. I doubt whether it acts as a very important reservoir elsewhere, though in St. Vincent it is often heavily infested very far from cane. It is far otherwise with *Paspalum virgatum*, which is a favourite

* This is in opposition to Wolcott's findings, but his heavy infestations in dry areas are under irrigated conditions, a fact which would seem to invalidate his argument.

host of *D. canella* wherever it occurs—at suitable points throughout the mountain zone (up to 1,800 feet, near Grand Etang), the middle belt and in swampy spots even in the dry belt. These grasses, of course, act also as a reservoir for parasites, which there find their prey much more accessible than in cane.

This list of grass-hosts is probably very far from exhaustive. There are several other abundant grasses in Grenada which have been recorded elsewhere as occasional hosts of *Diatraea* spp. These include the giant reed or roseau (*Gynerium sagittatum*), calimette (*Paspalum saccharoides*), panache or foxtail (*Andropogon bicornis*) and bâtard mavette or male mavette (*Setaria barbata*).

3. Natural Enemies.—Both the time and the material procurable were insufficient to yield adequate figures of the extent to which the borer is attacked in sugar-cane and grasses, by its various enemies. Parasites of *Diatraea* in general may be divided into those attacking eggs, larvae and pupae respectively. Trinidad would appear to be the northern limit of pupal parasites, since none was found in Grenada. What is of greater practical importance (since pupal parasites are of little significance in *Diatraea* control) is the fact that the two occasionally efficient Tachinid parasites (*Paratheresia claripalpis* and *Stomatodexia diadema*) found in Trinidad do not occur in Grenada. Grenada itself is the northern limit of *Ipobracon grenadensis* which, however, is never in my opinion an efficient parasite of borers in cane. I have elsewhere pointed out how greatly handicapped these wasp parasites are, by the great thickness of material which, in sugar-cane, they have to pierce to reach their prey. Tachinids, on the other hand, are not thus embarrassed, since the young larvae are deposited at the mouth of the borer tunnel.

Another wasp-parasite, *Microdus stigmaterus*, which is widespread on the mainland and also on all except the driest of the West Indian islands, is abundant in Grenada, but never, for the above reason, very efficient in cane. A collection of 49 black-headed borers (*D. saccharalis*) in *Valota*, was parasitised by *Microdus* at the rate of 12 per cent.

As regards egg-parasites, it is curious that I found not a single case of parasitism by *Trichogramma*, while *Prophanurus* was surprisingly plentiful. It has, however, been recorded in the island.

There follows a list of the parasites of *Diatraea* in Grenada :—

Attacking the egg :—*Trichogramma minutum*
Prophanurus alecto (a new record).

Attacking the larva :—*Microdus stigmaterus*
Ipobracon grenadensis. A slender black earwig (predator ; a new record) *Bracon femoratus* (Box, 1928, p. 7. I have been unable to trace this species in Grenada).

The combined attack of these, at least on the borer population in sugar-cane, is probably almost negligible economically and there is a clear and promising field for the introduction of one of the three more efficient of the Tachinid parasites known (*Lixophaga*, *Paratheresia*, and *Metagonistylum*) and of a specific parasite, when found, for *Diatraea canella*. Conditions in the future commercial cane-growing areas would almost certainly be too dry for *Metagonistylum* (the Amazon fly) ; so that either *Lixophaga* or *Paratheresia* is indicated for introduction against *D. saccharalis*. I suggest that, as the present borer infestation is comparatively small, the decision may wait a year or two until we know the results of experiments with both these flies now under way under similarly dry conditions in Antigua and Barbados. In the meantime it would be advisable to survey the infestation from time to time and I would suggest that arrangements be made for Mr. Box, who is in charge of borer work in the Leeward Islands and in St. Lucia to pay periodic visits to Grenada.

Cane froghopper (*Tomaspis saccharina*) :—Before leaving the subject of sugar-cane it might be mentioned that the Trinidad froghopper, the range of which, missing Tobago, extends as far north as St. Vincent, is widespread in Grenada, from sea-level to at least 2,000 feet, and is occasionally and locally abundant. It must be reckoned with by the developing sugar-industry.

V. Cacao Pests.

Cacao thrips is apparently less serious this year than usual. I saw no considerable infestation. It is generally considered by far the worst cacao pest in the island.

I was asked especially to examine a termite (*Calotermes* sp.) said to be responsible for widespread damage to living cacao trees. Most attention had been paid to it by Mr. Parry Okeden, at Hermon. The infested cacao, which we examined in company with Mr. David Lang, was growing on a rather steep slope, about 500 feet above sea-level, unshaded as usual in Grenada and facing the prevailing wind from the sea, only a few miles distant. All the trees showed rather more than usual dead bare tips due largely to this wind. Larger branches were dead also with *Diplodia Theobromae*. Practically every tree on the slope was infested by the termites, and there had been very extensive and assiduous cutting away of infested branches. The favourite point of infestation seemed to be the transition zone between dead and living tissue, usually at a point where already bored wood had been cut away. I saw not a single instance of their presence in the absence of dead wood, and no indication whatever that the infestation is anything but purely secondary. (Cf. Nowell's discussion of *Diplodia* itself). The question is which comes first, the dead wood or the termites. I was able to point out plenty of dead wood, caused by wind and by *Diplodia*, with no termites.

Mr. Okeden, however, and Mr. Lang assured me that they have seen an infestation in a branch which was perfectly healthy both above and below, and had no wound at the point of entry. This I should like to see. In any case there can be no question that the termite does prefer the transition zone between already existing dead and living wood, and that these favourable conditions are immensely increased by the continued cutting back of infested stumps to the living tissue, without the application of any deterrent such as tar or creosote.

VI. Summary.

1. The banana borer has no wild host-plants and no known parasites; hence it is especially amenable to direct control measures—plant selection, plantation hygiene and trapping.

2. The present infestation is very much lower than one would have expected, from comparison with Jamaican and Haitian conditions.

3. The question as to how much this is due to special Grenadian conditions will be settled when large scale production is in full swing and vast quantities of cut pseudostems and stumps invite infestation.

4. The most important method of prevention lies in the rigorous selection of clean planting material.

5. Potential breeding-material, whenever possible is preferably gathered into pens where it may be converted into manure.

6. Trapping, preferably by means of 1-foot lengths of split pseudostem placed on the ground, certainly seems effective in Grenada.

7. The two sugar-cane moth-borers (*Diatraea saccharalis* and *D. canella*) in Grenada infest this crop to the extent of about 42 per cent. of the stalks and nine per cent. of the joints.

8. Cane in Grenada is, however, at present grown almost entirely under what amounts to peasant conditions, namely small patches separated by wasteland and by other crops. When the industry is extended on an estate basis a somewhat higher infestation is to be expected.

9. Six different wild grass-hosts are known in Grenada. Of these only two are important as reservoirs of the borer, and here as elsewhere, they act as reservoirs of the parasites too, since in them the borer is much more accessible than in cane.

10. Of the five (or possibly six) parasites (and predators) of *Diatraea* found in Grenada, none is of very much practical importance, and there is a clear field for the importation of either *Lixophaga* or *Paratheresia* (efficient Tachinid parasites) and of a specific parasite when found, for the yellow-headed borer, *D. canella*.

11. The decision as to *Lixophaga* or *Paratheresia* should be deferred till the results of experiments in Antigua and Barbados are available.

12. The Trinidad froghopper is widespread and occasionally abundant in Grenada.

13. A termite (*Calotermes*) infesting living cacao was examined, but no evidence was seen that it was anything but secondary. It is recommended that pruning of infested branches should be followed by the application of tar, creosote or other deterrent.

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ECUADOR'S COCOA INDUSTRY.

According to a report by His Majesty's Charge d'Affaires and Consul-General, Quito, published by the Department of Overseas Trade, 1934, Ecuador's cocoa production has been falling rapidly during the last 14 years in consequence of witchbroom and other diseases in the plantations, and the present output shows a decrease of more than 77 per cent. as compared with 1920. This has naturally affected the country's finances: in 1920 cocoa exports represented 71 per cent. of the total, while in 1933 they represent less than 20 per cent. The amounts produced and exported during the period 1930-33 were :—

	Produced Quintals (101 lbs.)	Exported.	
		Kilos.	Value in Sucres.
1930 ..	387,430	20,081,734	23,403,591
1931 ..	283,189	14,634,170	12,254,544
1932 ..	300,468	15,429,570	11,267,325
1933 ..	239,227	10,580,000	8,720,347

The crop during the first six months of 1934 was very encouraging and deliveries showed a large increase as compared with those of similar periods during the previous five years, as will be observed from the following figures :—

	Deliveries during the first half year. Quintals of 101 lbs.
1930	264,895
1931	209,820
1932	246,976
1933	169,328
1934	268,327

The exports from January to June, 1934, went principally to the United States, Germany, Holland and France.

DIATRAEA ALBICRINELLA Box, A SPECIES NEW TO THE TRINIDAD FAUNA.

By Harold E. Box, F.R.E.S.
Imperial College of Tropical Agriculture.

On the 13th October, 1934, during a brief visit to Trinidad, I was privileged to accompany Sir Charles Belcher and Dr. J. G. Myers on a little expedition into the heart of the Nariva Swamp. We followed for about seven miles a trail that had been made some months previously by the oil interests, and I understand that the part visited by us had not before been explored by naturalists. Not the least of the several interesting discoveries made on that unforgettable occasion was that of a few larvae of a *Diatraea* species, boring in the thick succulent stalks of the giant grass *Panicum grande*, growing in about two feet of water near the edge of the Guatecare River, which penetrates the Nariva Swamp for a considerable distance.

These borers were of a form quite new to my experience, but Dr. Myers stated that they reminded him of some found in sugar-cane on the Parana da Eva, Lower Amazons, in November, 1933, subsequently reared to the adult stage and determined as *D. albicrinella*. More recently Mr. D. Vesey Fitzgerald has found similar larvae in *P. grande* at other localities in Trinidad, and adults reared from these have been sent to me through the kindness of Mr. Alan Pickles, enabling me to confirm the identification of the species.

Prior to Myers' discovery on the Amazons, *D. albicrinella* was known only in the adult stage, and was described by me in 1931 (1) from a series of 15 males and 20 females from British Guiana (Potaro), the Upper Amazons (Fonte Boa being the type locality), and various localities in Peru and Ecuador.

Dr. Myers is shortly publishing (2) a valuable contribution to the ecology of certain South American *Diatraea* species, in which the finding of *D. albicrinella* is mentioned; this borer occurred in company with *D. saccharalis* (Fabr.), and both species were attacked by the Amazon Fly (*Metagonistylum minense* Towns.). Myers also gives a very good description of the "strikingly beautiful" larvae, but the following notes, based on the Nariva specimens, may also be worth placing on record: Head light castaneous. Prothoracic plate slightly darker, with a light coloured dorsal streak; blackish laterally. Posterior mesothoracic bar long and narrow but slightly broader dorsally, forming a very shallow triangle; otherwise as in *saccharalis*. Legs blackish. Body dirty whitish, becoming purplish-fuscous laterally, forming two sharply defined broad lateral stripes separated by a whitish dorsal stripe; these stripes obsolete on the thorax*. Body segments with dark chitinised areas ("tubercles") surrounding the principal setae dorsally and ventrally, or groups of setae laterally, forming the characteristic *Diatraea* pattern. The setae appear to be somewhat longer than is usual in *Diatraea*. A larva approaching maturity measured 22 mm. in length.

I have seen pupa-cases from Myers' Amazons material (males), as well as two (females) sent to me by Mr. Pickles. The pupa is generally similar to that of *saccharalis*, but the posterior abdominal spines are longer and sharper.

The moth is rather large (wing expanse: male, 26-33 mm., female, 32-45 mm.), with light to dark buff forewings and pearly-white hind-wings. The forewing has a dark shaded area at the apex and another along the inner margin; there are two well-defined series of fuscous spots, forming diagonal lines from the apex of the forewing to the inner margin, and in well-marked specimens these spots are almost coalescent, forming denticulate lines across the wing. The characteristic feature of the species, however, is the presence of large conspicuous tufts of whitish hair-like scales on the posterior tibiae of the male.

From the three original larvae found in the Nariva Swamp no adults were secured; one of them was parasitised (by *Microdus* sp.) and the others died in captivity. A further visit was made to the original locality by Mr. Fitzgerald in December, but without any success whatever. "The water had risen so high as to make the *Panicum grande* quite inaccessible". (Myers *in litt.*)

Subsequent searches for this interesting *Diatraea* resulted in the discovery by Dr. Myers and Mr. Fitzgerald, on 3rd January, 1935, of larvae and pupae (one of the larvae being parasitised by *Microdus*) in *Panicum grande* at Guayaguayare, near the south coast. On 10th January Mr. Fitzgerald found the species in the same host at Plum Road, Mitan, and succeeded in rearing adults from the early stages secured.

More recently (April), Mr. Pickles communicates that larvae of the type of *albicrinella* are being reared from *Panicum grande* and *Typha angustifolia* from the Caroni Swamp. The finding of *Diatraea* in one of the *Typhaceae* is extremely interesting, as the previously known food-plants are, with a single exception (*Cyperus* sp. in British Guiana), all members of the Natural Order Gramineae (Poaceae).

Diatraea albicrinella is the seventh species of the genus now known in Trinidad, the others being *saccharalis* (Fabr.), *lineolata* (Walk.), *impersonatella* (Walk.), *canella* Hamps., *bellifactella* Dyar, and *minimifacta* Dyar. So far, no records are forthcoming that *albicrinella* attacks any

* Mr. Pickles states (*in litt.*) "inflated larvae show no signs of the longitudinal stripes which are such a striking character of the living larva. The stripes appear to be located on the body wall itself and consequently are removed when the cuticle is emptied".

hosts of economic importance in Trinidad, but as it is known as a sugar-cane borer in the Amazons region its economic status needs to be watched.

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REVIEWS.

UNITY, NATIONAL AND IMPERIAL.

By H. Martin Leake SC.D. (Camb.), with a Preface by Sir Edward Grigg, K.C.M.G., K.C.V.O., D.S.O., M.C., M.P., *G. Allen and Unwin Ltd.*, London, 1935, pp. 320. 8*s*. 6*d*.

Sir Edward Grigg describes this book in his Preface as "devoted to two problems which our statemanship cannot wisely continue to ignore—the financial basis of agriculture in this country and the practical meaning of trusteeship as applied to agricultural production in the tropical Colonies".

There is much in what Dr. Leake says, which will be of great interest to professional readers. He has at any rate succeeded in giving many of us, who have spent our lives in tropical countries as general administrators, a clear and closely reasoned appreciation of the limiting conditions, physical and human, to progress towards the reconciliation of the demands of civilization and the imperative duty of fostering "the well-being and development" of the native peoples. He has cleared up much that we have been dimly conscious of, and it would be well if his book could be placed in the hands of all those whose path in life is leading them to the tropics. Even the experienced administrator will find in it collated information and fresh ideas, which cannot fail to be of great value to him. To explain from this point of view it seems necessary to attempt to summarize, though no summary can do justice to the wealth of argument and example.

The main theme is the unification of the development of agriculture at home and in the Colonies with other activities of national life; and the main object is to explore the obstacles which stand in the way, and to find a means of surmounting them.

At home Dr. Leake finds industry far ahead of agriculture in its organization of finance and technique. A balanced unity must be restored. Recent action has concentrated too much on prices and too little on costs. We need a stable, efficient and properly graded organization, which can command the confidence of the money market and into which we can all put our savings. State measures to give long and short term credit or create small holdings, though they may do something, can be no real substitute for this. On the technical side the gap between research and field practice must be bridged and organization must be strong enough to accomplish this.

In the tropical Colonies conditions may be different but, here too, lack of unity of purpose stands in the way. There is the greater need of this because prosperity and progress must depend on "exchange cultures" and modern conditions in the world markets are rendering their stable production increasingly difficult. A policy which merely aims at giving the inhabitants a definite, or even an increasing, share in the administration must be lopsided. Economic progress, and social progress based on this, must come first. Sharp conflict between the interests of dealer and peasant producer must be avoided. A plantation system largely under alien control and working for cash profit with no outlet for native intelligence and enterprize must fail to satisfy. Education must come but "the educational ladder must lead to greater opportunity in agriculture or the basis industry will be drained of its most intelligent workers". And, it may be added, efforts to improve peasant cultivation must be hampered by lack of assistance from the class from which the peasants are drawn.

Dr. Leake explores alternatives and gives credit for a success achieved. It is in cooperation that he finds the path to unity. But horizontal cooperation, though it may accomplish much, cannot succeed completely, if it is unable to control field practice. At home and in the tropical Colonies the real solution would seem to lie in Vertical Cooperation, organized by Syndicates or Corporations on a sufficiently large scale to give financial stability and to control or guide all operations from production in the field to the marketing of the product, with a complete staff of all essential grades. In both cases some measure of control by the State would be needed, if only of profits. In the Colonies there would be a triple partnership between the State as supplying transport facilities and other broad requirements, the Corporation and the peasants. The state's share in the profits would be in return for services rendered and as a solution of the problem of giving the general community an adequate share in the "unearned increment".

Two examples of a near approach to this ideal are examined in detail—the operations of the Sudan Plantations Syndicate in the Gezira and those of the Colonial Sugar Refining Company in Fiji, both, in some measure, developments of the ancient métayer system of the Continent. The latter approaches most closely though its

development has been due to fortuitous circumstances. It presents an outstanding and, Dr. Leake thinks, an almost unique example of the successful solution of the problem of reconciling the interests of business corporation and peasant farmer, largely because the Company has realized the vital importance of bridging the gap between field and factory, research and peasant, by a technical staff of "general practitioners" "acting as the peasants' friend and educators" and accepted by them as such. Success is proved by the maintenance of the standard of production, the keen competition for the farms and the large outside area which voluntarily submits to the necessary control.

True it is that, in this case, the peasant farmers belong by origin to hardworking agricultural castes from India, who had already established relations with the Company during their indenture days. Success might be achieved more slowly with more primitive peoples, but the essential principles remain the same. The present day obstacles in the way of financing large scale operations in the Colonies and finding a suitable field for them may be great, but it would seem clear that a promising trail has been blazed and the essential factors in the problem have been explored.

No scheme, however ideal, is worth a second thought if it does not offer the maximum of financial stability and, in his reference to Fiji and the organization of the Colonial Sugar Refining Company, Dr. Leake is concerned to show that not only does it conform in many essentials to this ideal but that it possesses that financial stability. It may be of interest, therefore, to conclude this notice with a brief examination of the divergencies, on which he lays less stress, for they would seem to point his moral. The Government has no share even in research work, except indirectly, and as a legacy from control of indentures. The business is a single crop monopoly and, indeed, from the Indian point of view, for practical purposes a monopoly of the only exchange culture of the Colony. Its operations are, of course, based on the still larger operations in Australia. It may be that its strong financial position and local monopoly have been peculiarly favourable to developments which, it must at any rate be recognized, have stabilized at a critical time the Indian community in the Colony as a permanent and prosperous element and the mainstay of primary production.

None the less, there are symptoms of lopsided development and risk to unity of stable progress. The single crop basis is dependent on the bounty of others for, if preference went, the sugar farm as at present organized would go out of business. The very success achieved has so far beguiled the Colony into comparative neglect of other sources and delay in organizing means of exploring them. "*Le bien est l'ennemi du mieux.*" The Indian area outside the sugar flats is considerable and still waits effective development. The risk of suspicions of profiteering and stranglehold in the minds of the peasants is inevitable to the monopoly. It is accompanied by some lack of appreciation of the real advantages of the sugar farm with no other standard with which to compare it. There would seem increasing need of variety of resource and probably of greater attention to the production for home consumption of food staples at present imported at high cost.

But there is more than this. The system does not pretend to offer its suppliers any "outlet for intelligence or enterprize" above the peasant level. It has accomplished much and cannot be expected to do everything at once; but neither the Company nor the Colony can afford to neglect the danger of failure to learn Dr. Leake's lesson.

One further point emerges, of some general importance to all such schemes. Experience in Fiji shows that, even with the best provision for farm needs, a stable outturn and a secure market with some laxity of the law of crop lien can tempt the peasant into improvident borrowing even to the extent of causing grave concern to the operating Corporation. If this, as is not impossible, leads to cooperation between all parties concerned to mitigate the danger, it may prove of actual benefit to the cause of unity of progress towards common ends.

R. J. PEARSON, C.I.E., I.C.S. (retd.)

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THE OIL PALM IN MALAYA—MALAYAN PLANTING MANUAL No. 1.

Published by the Department of Agriculture. Straits Settlements and Federated Malay States, By B. Bunting, N.D.A., F.L.S., C. D. V. Georgi, O.B.E., B.SC., F.I.C., and J. N. Milsum, F.L.S. Price $2 (S.S. currency) 1934.

This publication replaces the special bulletin under the same title, published as No. 39, and is the first of a new series of Malayan Planting Manuals, to which it is hoped to add other works from time to time.

The aim of the present publication, as expressed in a brief preface by the Director, is to present a reasonably complete comparison of information concerning the crop. It is an excellent example of team work, for of the three authors, Messrs. Bunting and Milsum are agricultural officers with an intimate knowledge of the cultivation of the Oil Palm, while Mr. Georgi is the Agricultural Chemist and deals very competently with the composition of the fruit and its extraction in the factory. Furthermore, the assistance of the Entomologist and the Mycologist in the Department has been obtained for the chapters dealing with the insect pests and fungoid diseases of the palm.

The book is very complete, and though it does not claim to deal with conditions other than those that obtain in Malaya, may be recommended to any one interested in the production of Palm oil. It is excellent value in everyway, for it is well printed and fully illustrated.

R. C. W.

THE LABORATORY.

Its place in the modern world. By D. Stark Murray, B.SC., M.B., CH.B. *The Fenland Press*, London, pp. 117. Price 3*s*.

The laboratory of the fiction writer is usually far removed from the truth—retorts and cupolas still figure in the foreground. The laboratory of the schoolboy is chiefly furnished by racks of test tubes emitting foul odours. The modern research laboratories have little resemblance to either of these, and each is adapted to its special purpose. This interesting little book gives an excellent idea of the range of subjects studied and the general function of laboratory work in various branches of science and medicine. The laboratory worker will probably open the book with a certain amount of cynicism, but perusal of a few pages will show him how interesting are the problems investigated by research institutes of which he may have heard only the names. Anyone whose knowledge of laboratories is confined to conducted towns will certainly gain a new outlook and a broad understanding of the aims of the research worker. The flavour of the author's speciality, pathology, lingers throughout the book, and provides a fascinating background for his observations.

D. W. D.

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SCIENTIFIC RESEARCH AND SOCIAL NEEDS.

By Julian Huxley, *Watts & Co.*, London, pp. 286. Price 7*s*. 6*d*.

Any book by Professor Julian Huxley commands attention, and here he has given an excellent account of the various fields of research in science and medicine. He shows particularly well the relationship between the "long-range" research of the Universities and industrial research which aims at the immediate application of results. Although technical discussions are carefully avoided, the descriptions are clear and complete. The book is built up from a series of broadcast talks, but it is perhaps unfortunate that it includes several dialogues between the author and Professor Levy, Sir Thomas Barlow and Professor Blackett. The fascination of listening to informal discussions is lost when the conversation must be read like a play. Nevertheless, this part is so small that it does not detract from the charm of a book which is certain to be very widely read.

D. W. D.

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FERNS OF ANTIGUA.

A list of 34 species of Pteridophyta from Antigua (33 ferns and one *Psilotum*) by A. N. G. Alston, appears in the *Journal of Botany*, February 1935. This list is based on a collection by H. E. Box, believed to contain all the species of ferns and fern-allies occurring in a wild state in the island, and is prefaced by a brief ecological outline of Antigua vegetation by H. E. Box.

THE SOUTH AFRICAN SUGAR YEAR BOOK AND DIRECTORY, 1935.

Compiled and edited by H. O. Andrews, M.J.I., Durban, 1935, price 5*s*.

We have to hand the sixth edition of this well-known and equally well edited book, which may be regarded as a published record of the past season's achievements in the South African Industry. One wonders why other countries do not follow in South Africa's footsteps and thus, in time to come form a compact library of the growth and development of the world's sugar industries. The book describes the improvement which has taken place since 1932, although last season was one of unusual rains, low sucrose in cane and locust visitations. It is profusely illustrated and well divided up into sections, all of which are of interest to others besides South Africans.

J. G. D.

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SUGAR FACTORIES AND SUGAR MACHINERY*.

By William Kilpatrick, Institution of Mechanical Engineers, London, 1935, pp. 615-684.

A reprint of this paper has been presented to the College Library through the kind offices of E. C. Buck, Esq., M.I.M.E., Port-of-Spain, Trinidad. The author is a Director of Duncan Stewart & Co. Ltd., the well known sugar machinery manufacturers, and reprints of his paper are distributed by Badcock & Wilcox Ltd., the boiler manufacturers.

As the title suggests, the paper covers every aspect of cane sugar manufacture and it is profusely illustrated with drawings of equipment and of flow sheets. There is no extended technical discussion but each step in the process, including steam generation and furnace types, is dealt with efficiently. From the technological point of view, we should point out a mis-statement in the description of the Carbonatation process which states that the large amount of lime used attacks the invert sugar. Actually, every precaution is taken to guard against such attack. Some useful comparative performance curves for centrifugals were given together with Appendix of tabulated data concerning evaporation, crystallizer performance and costs of production.

J. G. D.

* This paper was read before the Glasgow and West of Scotland Branch in Glasgow on 5th October, 1933.

FOR SALE.

"NATURE TEACHING" by Sir Francis Watts. 6th Edition 1934, price 3*s*. 6*d*. Obtainable from: The Secretary, West India Committee, 14, Trinity Square, London E.C.3., England.

ENTOMOLOGICAL NOTES.

By V. H. W. Dowson.

A List of Date Scale Insects and a Short Note on their Occurrence in Basrah.

Date Scale Insects.

Buxton, P. A. (*Bul. Ent. Res.* XI, 3) lists the following scales as known to attack date palms :— *Parlatoria blanchardi*, Targ. ; *Phoenicococcus marlatti*, Ckll. ; *Icerya aegyptiaca*, Douglas ; *Aspidiotus ostreaformis*, Curtis ;

A. *hederae*, Vallot ; *Chrysomphalus aonidum*, L. ; C. *aurantii*, Mask. ; *Coccus hesperidum*, L. ;

Rao, Y. R. (Dept. Agric. 'Iraq, Mem. 6) adds *Asterolecanium phoenicis*, Green ; and Professor F. S. Bodenheimer, of the Hebrew University, Jerusalem, informs the writer in a private communication (21-7-34) that *Chrysomphalus dictyospermi*, Morg. is well known on date palms in Africa Minor.

Basrah Date Scales.

Popenoe, P. B. (Date Growing in the Old World and the New, 1913) states that *Parlatoria blanchardi* and *Phoenicococcus marlatti* "are to be found throughout the whole date growing world". Buxton (*loc. cit.*) confirmed the presence of the former at Basrah and elsewhere in the 'Iraq, but failed to find the latter ; but Rao (*loc cit.*) found it common at Baghdad. The *Asterolecanium phoenicis* identified by Mr. E. E. Green from specimens of Rao Sahib Y. R. Rao were presumably collected at Baghdad ; but the writer has found this scale common at Basrah. The identification was confirmed by Mr. A. Dutt. Early in 1934, Prof. Bodenheimer identified a scale on a date leaflet, sent to him by the writer, from a Basrah date palm, as *Chrysomphalus dictyospermi*. He also identified this scale on citrus leaves supplied by the writer from Basrah on two occasions. On each occasion, the sample consisted of several leaves. No *Chrysomphalus aurantii* was found, and the writer's belief that its presence in Basrah has yet to be proved thus receives encouragement. On the other hand, *C. dictyospermi*, which is common in Basrah, attacks dates as well as citrus, and were any campaign for its eradication on citrus to be launched, such a campaign could not afford to neglect its eradication on date palms. The cleaning up of 100,000 acres of date palms may well present difficulties of quite another order to that of cleaning up a few thousand citrus trees. Up to the present, however, only one palm has been found infested with this scale.

In order to collect information concerning the relative incidence of *Parlatoria blanchardi* and of *Chrysomphalus dictyospermi*, a specimen leaflet was collected from every infested date palm in the first 14 blocks of the Kutas-Sayyid Estate which are situated nearest the river. The specimens were sent to Professor Bodenheimer, who reported that all the scales were *P. blanchardi*. Out of 6,954 palms inspected, 250 were infested with this scale, or a little over 3½ per cent.

Damage by Scales in Basrah.

From the result of the count, it would appear that the common scale on palms in Basrah is *Parlatoria blanchardi*. This does not do a great deal of damage, although its presence is sometimes revealed by the colour of the palms which look grey instead of green. Shoots are much more commonly attacked than adult palms, and it would seem that palm shoots grow out of their susceptibility to attack. Owing to the difficulty of inspection the incidence of attack on very old, and therefore very tall, palms, is not known. Palms which are weakened by prolonged drought appear more attacked than others.

Scales are uncommon on date fruit. Although detailed examinations of fruit for scales have not been made, and those found have not been authoritatively identified, the writer believes that the scale found on fruit is usually *Asterolecanium phoenicis*.

Treatment.

The Basrah practice for the control of scale on palms is the severe pruning away of infested fronds. The new fronds which sprout are in general comparatively free from infestation, so that the treatment may be said to be successful. No treatment is adopted against scale on the fruit.

* * *

Note on the Resistance of the Fig Moth *Ephestia cautella*, Walk to Cold.

One hundred dates of the *Khadrawi* and Usta 'amran variety were stoned and a larva of the fig moth inserted in each. Every date was subsequently placed in a corked test tube which was put in cold storage at a temperature which ranged from 35° to 43°F. No humidity records were taken, the only guide to this being the behaviour of dates stored in bulk in cold store, where it was observed that their moisture content apparently remained unaltered for a year or more.

The hundred test tubes were put in cold store on 14th February, 1934, and each day thereafter, until 25th May, one of the tubes was taken out and placed in an office at room temperature. On 22nd June all the tubes were examined. It was found that the larvae which had developed into adult moths were removed from cold store on the following dates (the number of days each tube remained in cold store is shown in brackets) :

Feb.—15 (1) ; 17 (3) ; 18 (4) ; 22 (8) ; 24 (10) ; 26 (12) ; 27 (13) ; 28 (14). Mar.—2 (16) ; 5 (19) ; 10 (24). Apr.—22 (67) ; 28 (73) ; 30 (75). May—7 (82) ; 10 (85).

It was to be expected that the larvae which remained in cold store for only a short time would develop into moths but surprising to find that after an internal of 42 days, from 10th March to 21st April, during which all tubes removed contained only dead larvae, a period of 18 days occurred when five larvae were found alive and developed into moths. Under the conditions of the experiment it will be seen that fig moth larvae can remain alive for 85 days at a temperature varying from 35° to 43°F. The test tube removed from cold store on 24th April contained a larva parasitised by what appeared to be a *Habrobracon*.

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

New Substance for Wrapping Citrus Fruits.

Experiments are being made in Arizona in wrapping grapefruit with a new substance, known as Pliofilm. This material is thin and orange-coloured and looks much like cellophane but is very tough and elastic. It is said it will stretch to several times its own length and is impervious to air or moisture. The *Arizona Producer*, in reporting on tests with this material states that grapefruit wrapped in it on 16th May, were plump and firm when examined on 29th June, losing only about four per cent. in weight, while check fruits had lost about one-third in weight, and were leathery and uneatable.—(*Hadar*, Vol. VIII. No. 2, p. 54, 1935.)

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Citric Acid from Molasses.—*F. J. Chan.*

Citric acid can be produced by fermentation with *Aspergillus niger* for 38 to 60 hours on solid materials containing sucrose or molasses. The citric acid yield is 45 per cent. of the sugar content of the molasses and 55 per cent. of the sucrose if pure sucrose is used, based on the materials introduced into the fermentation. The sugar solution is absorbed on beet pulp or cane pulp which furnishes a large surface for the fungus growing in the spore-forming state. Sterilization of the mass to be fermented is not necessary, because the citric acid which is formed after one day surpresses the growth of the contaminating organisms. Sliced fresh sugar beet cannot be fermented directly. The cellular structure of the beet must be broken down first; otherwise the hyphae of the growing fungus cannot reach the sucrose-containing cell sap. This breaking down of the cellular structure can be accomplished by steaming at atmospheric pressure. When a certain type of beet was steamed for the short period of 20 minutes, the subsequent fermentation furnished citric acid; on the other hand, when the beet was autoclaved at a pressure of 15 pounds per square inch (0.9 kg. per sq. cm.) for the same length of time or longer, the end product from the author's fungus strain consisted only of carbon dioxide. This is peculiar, since the sucrose content in the beet slices does not change by this heat treatment at 115°C. The inversion of the sucrose is extremely slight. A number of comparative experiments were made in which bagasse impregnated with molasses was fermented; sterilization by autoclaving was used in some cases and no sterilization or pasteurization in the others. No improvement could be shown by sterilization. A decided advantage of bagasse as compared with beet pulp is its cheapness and the fact that the bagasse can be used several times over without lowering the yield. The yield of 19 per cent. citric acid with molasses, introduced as an experiment 11 on the combination of bagasse and molasses (experiment 11 is typical of ten experiments) was obtained when fresh sugar-cane was used for the preparation of the bagasse. Instead of bagasse from fresh sugar-cane, baled bagasse (a raw material for the manufacture of insulating board) was used. The carbohydrates left in this baled bagasse from the cane sugar manufacturing process undergo spontaneous fermentation. The yields of citric acid from the combination of baled bagasse and cane molasses were smaller than the yields on fresh bagasse impregnated with cane molasses and a longer period of fermentation was necessary.—(*Ind. & Eng. Chem.*, Vol. XXVII, p. 201, 1935. (Abstracted in *Facts about, Sugar*, April, 1935, p. 150.))

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Sunn-Hemp Retting.

The importance of establishing Indian sunn-hemp fibre firmly in the British market, where it is employed for the manufacture of such articles as ropes, cables, twines and nets, has been brought into prominence in recent years as a result of the investigation conducted by the Empire Marketing Board. It has been found that crude and careless methods of retting stand in the way of its more extensive use in the United Kingdom and also lower its value. Arrangements were therefore made during the year for the retting of sunn-hemp in the laboratories of the Madras Industries Department, and a careful study was made of the temperature of the water, the effect of changing the water, the quality of the water, and the duration of the retting period. Important conclusions have been arrived at, but the experiments are to be repeated on a larger scale this year.—(*Ind. and Eng. Chem.* News Edit. Vol. XIII, No. 6, p. 115, 1935.)

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Soil Survey for Hawaii.

In Washington recently the sum of $7,500 was allotted out of Hawaiian sugar processing tax funds to initiate a soil survey of the territory has been made by an order approved by the President. The allotment is made under the provision of the Jones-Costigan act authorizing expenditure of processing tax funds from sugar grown in insular areas for the general benefit of agriculture in those areas. The purpose of the survey will be to obtain comprehensive data on soils in various areas of Hawaii to serve as a guide in the further use of the land, particularly for crop diversification. It will be made by the Bureau of Chemistry and Soils of the Department of Agriculture in collaboration with the University of Hawaii.—(*Facts about Sugar*, April, 1935, Vol. XXX, No. 4, p. 130.)

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Labour-Saving Devices in the Factory (Oliver Filter, Electrical Welding, Trash Separation). —*W. J. Maze.*

The Oliver Campbell filter has, in those factories which have installed it, reduced the labour requirement somewhat. Practically every factory in the Territory is at present equipped with at least one electric welder. It is doubtful if any piece of equipment that was ever purchased by a plantation pays the dividends that an electric welder does. Recently the Labour Saving Devices Committee made an experimental installation at Honomu Sugar Company of a flotation tank in an attempt to float trash out of flume cane. While the experiment was of only a temporary nature, it proved that it should be possible with the proper installation to remove at least 60 per cent. of the trash that now goes through the mill when cane is flumed. Since the advent of some of the newer varieties of cane, particularly P.O.J. 36, the trash problem has become more acute than formerly. It would seem that any factory that instals the proper equipment for the floating of trash out of cane at the mill will realize a definite profit from this installation.—(*International Sugar Journal*, Vol. XXXVII, No. 438, 1935, p. 238.)

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Estimation of the Maturity of a Field of Cane, using the Hand Refractometer.—*H. H. Croucher.*

A hand sugar refractometer was purchased by two planters in Jamaica during the year and was submitted to the Laboratory for tests. It enables tests for Brix values for cane juice to be made in the field without the use of a mill, but the accuracy with which an estimation of the maturity of a field of cane can be obtained by use of the instrument depends upon three main factors: (*a*) the accuracy with which the instrument shows the Brix value of the extracted juice under local conditions, (*b*) the accuracy with which the small sample of juice extracted from the cane represents the average juice of the whole cane, (*c*) the accuracy with which a sample consisting of a limited number of canes can represent the standing of a whole field.

These three factors were approached in the following ways: (*a*) Cane juices were tested with the refractometer and with standard Brix hydrometers, when the refractometer gave slightly lower values than the hydrometers, (*b*) the juice of a sugar-cane is known to vary in total solids content throughout the length of the cane. Various methods of obtaining an estimate of the average content of the juice for the cane by using a minimum number of samples, were tried. Readings approximating most closely to those obtained by testing the juice from the whole cane were obtained by dividing the cane into three equal portions, making determinations on samples from the centre node of each section, and taking the mean of the three results. (*c*) The difficulty of obtaining a small sample of cane which is representative of a whole field of cane has been demonstrated in many countries. It has been shown that the only method of obtaining a reasonably small sample is by careful selection of average canes. In view of this experience, the sampling method adopted in Queensland has been recommended. It consists in selecting one cane of apparently an average degree of purity from a selected stool in each acre of the field. It has not been possible to test this method under local conditions.

It has been possible to obtain an instrument for Departmental use during the coming crop, and it is proposed to continue investigations. Provided reasonable accuracy in sampling a field of cane can be obtained easily, the instrument should prove invaluable to many of the sugar factories of Jamaica which do not possess facilities for testing a large number of cane juices. In making the investigations recorded above, it was found that the corer for sampling supplied with the instrument was not entirely satisfactory. Improvements to the corer were discussed and submitted to the suppliers of the instruments. Corers embracing the suggested improvements are now supplied with the instrument.—(*International Sugar Journal*, Vol. XXXVII, No. 438, 1935, p. 230.)

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World Consumption Figures.

Willett & Gray estimate the world sugar consumption during the calendar year 1934 at 25,868,000 tons against 24,677,000 tons in 1933, an increase of 1,191,000 tons or 4.82 per cent. The following figures show the consumption for the past six years:—

1934	.. ..	25,868,000 tons.
1933	.. ..	24,677,000 ,,
1932	.. ..	24,985,000 ,,
1931	.. ..	26,422,000 ,,
1930	.. ..	25,272,000 ,,
1929	.. ..	26,080,000 ,,

—(*International Sugar Journal*, Vol. XXXVII, No. 438, 1935, p. 244.)

AGRICULTURAL NOTE BOOK.

Copies of Professor Wood's "Note-Book of Tropical Agriculture" (price 5 shillings) may be obtained on application to the Editor, *Tropical Agriculture*, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.*]

SUGAR.—Prices on the Home Markets have ranged as follows (c.i.f. per cwt.).

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
6th June	4	10½	8	7½
13th June	4	9¾	8	6¾
21st June	4	6	8	3
27th June	4	7½	8	4½
4th July	4	6¾	8	3¾
11th July	4	3¾	8	0¾
18th July	4	1¼	7	11¼
(19*th July*, 1934)	4	10½	8	6¾

Raw values have again been disappointing, declining by fully 3*d.* during the period under review (June). The market has been unsettled by the uncertainties of the American situation resulting from the judgment of the Supreme Court at Washington making the whole system of "Codes" illegal while unseasonable weather conditions have given refiners little inducement to enlarge their requirements. Considerable quantities of Cuban and San Domingan sugars have also been pressed for sale. Stocks of raws in the United Kingdom have, however, been dwindling and the position of the article in this respect is more hopeful. *C. Czarnikow Ltd.* report that interest in B.W.I. sugars has been maintained by Canadian refiners whose total purchases to date amount to about 165,000 tons. The beet subsidy is to be continued for another year as from 1st September.

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COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association.

	American Mid.	*Egyptian F.G.F. Sakel.*
7th June	6.83	8.10
14th June	6.76	8,05
21st June	6.79	8.05
28th June	6.85	8.03
5th July	6.97	—
12th July	6.98	—
19th July	7.02	—
(20*th June*, 1934)	7.17	8.66

The decision of the U.S. Supreme Court against the constitutionality of the N.R.A. codes upset the market for a time owing to the fear that the A.A.A. would also be involved. There was more confidence, however, when Senator Bankhead stated that the 12 cent loan plan was likely to be continued, and prices have responded accordingly. The market for West Indian Sea Island in Liverpool continues firm, sales comprising Nevis, Montserrat and St. Vincent from 15½ to 16 pence per lb.

COCOA.—Since our last report cocoa prices have been very firm despite the free arrival of Bahia cocoa to consuming centres, and with the West African crop commencing in October, first selling indications are usually noted in July. Should any advance in price occur this would only be seized upon by producing countries to make sales, while should an advance not occur, however reluctantly, producers will ultimately be forced to accept such prices as the market offers. Accra cocoa is being quoted at 22*s.*-23*s.* and locally $5.60 per fanega for Plantation cocoa is freely paid.—(*By courtesy of the Cocoa Planters, Association of Trinidad, Ltd.*)

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RUBBER.—Quotations for Plantation Sheet have ranged as follows:—

	pence per lb.
5th June	5 15-16
12th June	6 1-16
19th June	6 1-8
26th June	6
3rd July	5 15-16
10th July	5 15-16
17th July	5 7-8
(18*th July*, 1934)	7 1-16

Price fluctuations have been slight. The market has to a certain extent been influenced by the situation in France and also in the U.S.A. As from 1st July the permissible exportable percentage from Malaya and other restricting countries, except the Dutch Indies, was reduced from 70 to 65 and it is anticipated that this reduction will bring a substantial improvement in prices. The total American consumption for the first five months of 1935 comes to 219,192 tons which compares with 216,595 tons in 1934.

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COFFEE.—The market has been dull, values of Costa Ricas being again lower. Kenyas, of a somewhat poor quality attracted very little bidding. Blue Mountain Jamaica has met a poor and irregular response from the trade, a small quantity of fine selling at 203*s.* to 215*s.* 6*d.*

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COPRA.—Freer offerings have depressed the market, and values during the month have declined 35*s.* per ton. To-day's quotation for West India sorts is about £11 5*s.* per ton c.i.f. London or Liverpool.

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BANANAS.—The shortage of supplies of soft fruit has assisted the demand for bananas. There is no change in the price for Jamaicas, which continue to be quoted at £17 5s. per ton delivered London and £17 nearest station. Brazilians are also unchanged at £17 delivered nearest station.—(*West India Committee Circular*, 20th June.)